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ABSTRACT

An evaluation of TICCIT (Time-shared Interactive, Computer-controlled, Information Television) involved over 5,000 community college students in introductory algebra and English composition courses. Comparisons between computer-assisted instruction and lecture-discussion sections of the same courses focused on four aspects of student performance: course completion rates, achievement, attitudes, and activities (time allocation). Other evaluation questions focused on teacher attitudes, teacher role, and program implementation; including administration, site management, and courseware design goals. It was decided to construct objective and essay tests specifically for this program, to measure both end-of-course achievement and immediate learning. TICCIT had a significant positive impact on achievement. The dramatic decreases noted in course completion rates may be inherent in self-paced instruction because students who have trouble managing their own instruction are risks. Student attitudes towards TICCIT were often less favorable than toward conventional teaching methods, but attitudes improved when TICCIT couses were supplemented by small group discussion with an instructor. Results suggest that TICCIT may be inappropriate for community colleges since only those students with a strong initial grasp in the subject matter benefited substantially. In itself, computer assisted instruction is no panacea; results depend on factors involved in the instructional process. (CP)

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Evaluation of The TICCIT Computer-Assisted Instructional System in the Community College

Donald L. Alderman

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FINAL REPORT

VOLUME I

September 1978

EDUCATIONAL TESTING SERVICE
PRINCETON, NEW JERSEY

EVALUATION OF THE TICCIT COMPUTER-ASSISTED INSTRUCTIONAL SYSTEM IN THE COMMUNITY COLLEGE

FINAL REPORT

VOLUME I

Donald L. Alderman

Educational Testing Service
Princeton, New Jersey 08541

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The exemplary cooperation and strong support of the two community colleges selected as demonstration sites for the TICCIT program were essential to this evaluation. To the students and faculty of the Alexandria Campus of Northern Virginia Community College and of Phoenix College in the Maricopa County Community College District, we express our appreciation. The executive officers of the colleges, William E. Berry at Phoenix and the late Donald L. Bisdorf at Alexandria, recognized the importance of an independent evaluation and facilitated our work at the community colleges. Faculty members in the mathematics and English departments actively assisted us by reviewing instruments, offering constructive recommendations, and administering tests. The project directors for the colleges, Fred Morrison and Monica Sasscer, gave generously of their time and effort in order to ensure the smooth conduct of an external evaluation.

The developers of the TICCIT program, namely the MITRE Corporation in McLean, Virginia and the Institute for Computer Uses in Education at Brigham Young University, always extended their fullest cooperation and assistance. During the initial stages of the project, Edward Burr II of the MITRE Corporation began planning and making arrangements for an external evaluation. Later Wanda H. Rappaport kept us informed about the status of the project and patiently responded to our inquiries. As the leaders of the efforts to develop the computer system and curriculum materials, John L. Volk and C. Victor Bunderson endorsed the need for a full independent evaluation of the impact of the TICCIT program. Their interest and support undoubtedly contributed to our success in completing this evaluation.

Numerous persons at Educational Testing Service contributed their valuable expertise to the evaluation. Ernest J. Anastasio and William A. Mahler took part in the design of the evaluation. James S. Braswell and S. Irene Williams developed the achievement tests in mathematics; Gertrude C. Conlan and Michael Ward assumed responsibility for developing the achievement tests and essay topics in English. Paul W. Holland suggested the approach to data analysis followed in this report and also wrote the initial description of the statistical strategies for estimating treatment effects. The difficult and complex tasks of maintaining the data files and performing all analyses fell upon Diane M. Fry and Katherine Kornhauser. Their competent and efficient work deserves our special recognition and thanks. Finally, Lucy Harvey prepared the various reports

associated with this evaluation. Her patience and productivity enabled us to produce this report.

Anne L. McAlonan fulfilled a unique role as a staff member on the evaluation. She coordinated our activities at one community college and made substantial contributions to the design and refinement of various instruments. Much of the work involved in arranging for data collection and in supervising a field study became her responsibility. During the extended absence of the evaluation's project director due to a medical disability, Anne made sure that field activities took place on schedule. Her assistance was truly essential to the evaluation.

This report has benefited from the review and suggestions of various colleagues. Those who offered comments helpful in improving the report were: Alphonse Buccino and Conrad Katzenmeyer at the NSF; Thomas D. Cook as a consultant to the NSF; John L. Volk, Wanda H. Rappaport and C. Victor Bunderson of the TICCIT staff; Richard T. Murphy, Loraine T. Sinnott and Spencer S. Swinton of Educational Testing Service. Whatever deficiencies still exist remain the responsibility of the author alone.

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TABLE OF CONTENTS

Page

List of Tables x

List of Figures xiii

List of Appendices xiv

Summary and Conclusions xv

Chapter 1: Introduction 1

- 1.1 Background 2
- 1.2 Key Features of the TICCIT Project 5
  - Market Success 5
  - Local Facility 6
  - Available Hardware 6
  - Learner Control 7
  - Mainline Instruction 7
- 1.3 Description of the TICCIT System 9
  - 1.3.a Hardware 10
    - Computers and Peripherals 10
    - Special Devices 13
    - Terminals 14
  - 1.3.b Software 17
    - Operating Systems and Application Software 17
    - Data Entry and Courseware Processing 18
  - 1.3.c Courseware 19
    - Content 20
    - Structure 21
    - Strategy 24
- 1.4 Goals of the TICCIT Project 26
- 1.5 Purposes of This Evaluation 29
- 1.6 Matters Outside the Scope of This Evaluation 33

Chapter 2: Methods and Measurement 35

- 2.1 Design for the Evaluation 35
  - 2.1.a Focus of the Evaluation 37
    - Student Achievement 38
    - Course Completion Rates 40
    - Student Attitudes 42
    - Student Activities 44
    - Faculty Acceptance and Teacher Role 46
  - 2.1.b Comparison Groups 48
    - Criteria for Comparisons 49
    - Formation of Groups 51
    - Context for Comparison Groups 55

Page

2.2 Instrument Preparation and Properties 57
  2.2.a Student Performance 58
    Achievement Tests: Math 59
    Achievement Tests: English 76
    Student Attitudes 87
    Student Activities 96
    Student Characteristics 101
  2.2.b Faculty Acceptance and Teacher Role 102
    Faculty Attitudes 105
    Faculty Activities 108
2.3 Data Collection 109
  2.3.a Sampling 110
  2.3.b Schedule 113
2.4 Data Analysis 116
  2.4.a Assumptions 119
  2.4.b Mathematical Model 121
  2.4.c Parameter Estimation 122
  2.4.d Application 126

Chapter 3: Implementation of the TICCIT Program 133

3.1 Demonstration Sites 134
  3.1.a Site Selection 136
  3.1.b Student Profile 139
  3.1.c Target Courses 142
    Textbooks and Requirements 143
    Enrollment in Target Courses 147
3.2 Project Administration and Site Management 151
  3.2.a Mechanisms for Implementation 151
    College Liaison 154
    Coordinating Committee 155
    Implementation Plan 156
    Community College Authors 158
    Faculty Training Program 159
    Student Handbook 160
  3.2.b Staffing 160
3.3 Courseware 165
  3.3.a Instructional Design 166
  3.3.b Courseware Production 174
3.4 Summary 180

Chapter 4: Course Completion Rates 185

4.1 The Nature of Completion 186
4.2 College Grades and Rosters 188
4.3 Presentation of Results 192
  4.3.a Math Courses 194
  4.3.b English Courses 204

Page

4.4 Analysis of Program Effects 209
    4.4.a Math Courses 212
    4.4.b English Courses 219
    4.4.c Estimated Treatment Effects 226
4.5 Enrollment in Subsequent Terms 229
4.6 Discussion 235

Chapter 5: Student Achievement 241

5.1 Achievement and Students 242
    5.1.a Measures of Achievement 243
    5.1.b Populations of Students 245
5.2 Presentation of Results 247
    5.2.a Math Courses 249
    5.2.b English Courses 255
5.3 Analysis of Program Effects 260
    5.3.a Math Courses 261
        Common Objectives 262
        Ability and Content Subscores 272
        Unique Objectives 278
    5.3.b English Courses 281
    5.3.c Immediate Learning and Retention 289
    5.3.d Estimated Treatment Effects 291
5.4 Discussion 297

Chapter 6: Student Attitudes 303

6.1 Students and Attitudes 304
    6.1.a Population of Students 305
    6.1.b Measures of Attitudes 307
        Student Survey 307
        Response Format 308
        Factor Analyses 309
        Dimensions 311
6.2 Presentation of Results 314
    6.2.a Common Statements 316
        Scores 316
        Item Responses 319
    6.2.b Specific Statements 326
        Item Responses 327
        Student Comments 329
6.3 Analysis of Program Effects 332
    6.3.a Math Courses 334
    6.3.b English Courses 339
    6.3.c Estimated Treatment Effects 345
        Math Courses 345
        English Courses 349
6.4 Discussion 351

Page

Chapter 7: Student Activities 357

7.1 Activities across Comparison Groups 358
Plans for Further Courses and Future Work 364
Interpersonal Contacts 364
Study Time 365
7.2 Student Interaction with the TICCIT System 366
7.2.a Observations 367
Sampling 368
Observation Record 368
Results 369
7.2.b On-line Data 378
Learner Control Functions: Course Summaries 378
Learner Control Functions: Structure 381
Progress Reports 385
7.2.c Time and Learning 388
Time Spent on the TICCIT System 389
Time and Test Performance 391

Chapter 8: Faculty Acceptance and Teacher Role 393

8.1 Teacher Role 394
8.1.a Instructor Activities across Conditions 397
Activity Questionnaire 398
Sample 398
Questionnaire Data: Activities Specific to Course Sections 399
Questionnaire Data: General Activities 402
8.1.b Teacher Tasks Under the TICCIT Program 403
Observation Record 404
Schedule and Sample 404
Context for Teacher Role 405
Tasks of TICCIT Teachers 409
8.2 Faculty Acceptance 413
8.2.a Baseline Attitudes 414
Instrument 416
Response Rate 417
Analysis 417
Beliefs about Educational Practices 419
Attitudes Toward CAI 427
8.2.b Reactions to the TICCIT Program 432
Instrument 432
Response Rate 434
Exposure to the TICCIT Program 435
Dimensions and Contrasts 436
Change 447

Chapter 9: Comments from the Developers of TICCIT (The MITRE Corporation Hazeltine Corporation).......... 451
9.1 Comments on the TICCIT Evaluation 452
9.1.a Student Achievement 453
Math 453

Page

English 455
Summary 456
9.1.b Course Completion Rates 457
9.1.c Comments on Completion Rate Data 459
9.2 Post Demonstration Developments 468
9.2.a Commercialization of the TICCIT System 469
9.2.b New TICCIT Installations 469
Military Training 470
Special Education 470
9.2.c TICCIT Demonstration Sites -- An Update 471
Brigham Young University 471
Northern Virginia Community College 471
Phoenix College 472
9.2.d Current System Developments 472
9.2.e The Future of TICCIT 475
References (Chapter 9) 476
References 479

LIST OF TABLES

Page

Table 2.1 Pretest Reliability: Mathematics Courses 69
Table 2.2 Posttest Reliability: Mathematics Courses 70
Table 2.3 Aspects of Writing: Faculty Considerations in Rating Student Essays 79
Table 2.4 Essay Test Reliability: Correlations Between Raters (Phoenix) 81
Table 2.5 Essay Test Reliability: Correlations Between Raters (Alexandria) 82
Table 2.6 Pretest and Posttest Reliability: English Courses 88
Table 2.7 Reliability of Student Attitude Survey: Mathematics Courses 92
Table 2.8 Reliability of Student Attitude Survey: Mathematics Courses (Phoenix) 94
Table 2.9 Reliability of Student Attitude Survey: Mathematics Courses (Alexandria) 95
Table 2.10 Reliability of Student Attitude Survey: English Courses 97
Table 2.11 Reliability of Faculty Attitude Survey 107

Table 3.1 Student Profile 140
Table 3.2 Target Courses 146
Table 3.3 Enrollment in Target Courses 152
Table 3.4 Contents of Implementation Plan 157

Table 4.1 Exceptions to Class Conditions 190
Table 4.2 Course Completion Rates: Mathematics Courses (Phoenix) 195
Table 4.3 Course Completion Rates: Mathematics Courses (Alexandria) 197
Table 4.4 Course Completion Rates: English Courses (Phoenix) 205
Table 4.5 Course Completion Rates: English Courses (Alexandria) 206
Table 4.6 Analysis of Grades with Credit: Mathematics Courses (Phoenix) 215
Table 4.7 Analysis of Grades with Credit: Mathematics Courses (Alexandria) 216
Table 4.8 Analysis of Grades with Credit: English Courses (Phoenix) 221
Table 4.9 Analysis of Grades with Credit: English Courses (Alexandria) 222
Table 4.10 Estimated Treatment Effects on Course Completion 227
Table 4.11 Subsequent Term Enrollment: Mathematics Courses (Phoenix) 232
Table 4.12 Subsequent Term Enrollment: Mathematics Courses (Alexandria) 233

Page

Table 5.1 Achievement Summary: Mathematics Courses (Phoenix) 251
Table 5.2 Achievement Summary: Mathematics Courses (Alexandria) 252
Table 5.3 Achievement Summary: English Courses (Phoenix) 256
Table 5.4 Achievement Summary: English Courses (Alexandria) 257
Table 5.5 Analysis on Common Objectives: Mathematics Courses (Phoenix) 263
Table 5.6 Analysis on Common Objectives: Mathematics Courses (Alexandria) 264
Table 5.7 Analysis on Common Objectives: Mathematics Courses across Semesters (Phoenix) 269
Table 5.8 Analysis on Common Objectives: Mathematics Courses across Academic Terms 271
Table 5.9 Posttest Subscore Reliability: Mathematics Courses 275
Table 5.10 Analysis of Posttest Subscores: Mathematics Courses 276
Table 5.11 Analysis on Unique Objectives: Mathematics Courses 280
Table 5.12 English Achievement Results: Essay and Objective Tests (Phoenix) 282
Table 5.13 English Achievement Results: Essay and Objective Tests (Alexandria) 283
Table 5.14 Analysis for Immediate Learning: Mathematics Courses 290
Table 5.15 Analysis for Retention: Mathematics Courses 292
Table 5.16 Estimated Treatment Effects on Student Achievement 293

Table 6.1 Student Attitudes under the TICCIT Program: Varimax Primary Factors 310
Table 6.2 Attitude Summary: Mathematics Courses 317
Table 6.3 Attitude Summary: English Courses 318
Table 6.4 Student Attitude Survey: Item Responses across Instructional Conditions, Mathematics 321
Table 6.5 Student Attitude Survey: Item Responses across Instructional Conditions, English 323
Table 6.6 Student Attitude Survey: Item Responses Specific to Instructional Conditions 328
Table 6.7 Analysis on Common Statements: Mathematics Courses (Phoenix) 335
Table 6.8 Analysis on Common Statements: Mathematics Courses (Alexandria) 336
Table 6.9 Analysis on Common Statements: English Courses (Phoenix) 340
Table 6.10 Analysis on Common Statements: English Courses (Alexandria) 341
Table 6.11 Estimated Treatment Effects on Student Attitudes 347

Page

Table 7.1 Student Activity Survey: Item Responses across Conditions, Mathematics (Phoenix) 360

Table 7.2 Student Activity Survey: Item Responses across Conditions, Mathematics (Alexandria) 361

Table 7.3 Student Activity Survey: Item Responses across Instructional Conditions, English (Phoenix) 362

Table 7.4 Student Activity Survey: Item Responses across Instructional Conditions, English (Alexandria) 363

Table 7.5 Student Interaction with the TICCIT System: Summary of Observations 371

Table 7.6 Learner Control Functions: Rotated Factor Matrix 383

Table 7.7 Time Spent on the TICCIT System 390

Table 8.1 Instructor Activities Survey: Item Responses 400

Table 8.2 Instructor and Proctor Activities under the TICCIT Program 411

Table 8.3 Faculty Attitudes toward Educational Practices: Rotated Factor Matrix 420

Table 8.4 Faculty Attitudes toward Educational Practices: Varimax Primary Factors 421

Table 8.5 Faculty Attitudes toward Educational Practices: Item Responses across Divisions 425

Table 8.6 Faculty Attitudes toward CAI: Rotated Factor Matrix 428

Table 8.7 Faculty Attitudes toward CAI: Varimax Primary Factors 429

Table 8.8 Faculty Attitudes toward CAI: Responses across Divisions 431

Table 8.9 Faculty Attitudes toward the TICCIT Program: Rotated Factor Matrix 438

Table 8.10 Faculty Attitudes toward the TICCIT Program: Varimax Primary Factors 439

Table 8.11 Faculty Attitudes toward the TICCIT Program: Responses across Divisions 445

Table 8.12 Faculty Attitudes toward the TICCIT Program: Responses by Department 446

LIST OF FIGURES

Page

Figure 1.1 TICCIT Computer System 11
Figure 1.2 TICCIT Keyboard 16
Figure 1.3 TICCIT Mathematics Courseware 22
Figure 1.4 TICCIT English Courseware 23

Figure 2.1 TICCIT Math Units and Community College Courses 66
Figure 2.2 Examples of Problems from Math Posttests 68
Figure 2.3 Item Classification for Mathematics Posttests 73
Figure 2.4 Example of Item Coverage for Math Posttests 75
Figure 2.5 Examples of Item Types from Objective Tests of Writing Skills 85
Figure 2.6 Data Collection across Academic Terms 114
Figure 2.7 Data Base on Student Performance 117

Figure 3.1 Course Maps 168
Figure 3.2 Rule Displays 171
Figure 3.3 Instance Displays 172
Figure 3.4 Courseware Production Team 176

Figure 4.1 Completion Rates across Academic Terms 202

Figure 7.1 Course Summary of Learner Control Functions 379
Figure 7.2 Student Progress Report 386

Figure 8.1 Duties of a TICCIT Teacher 395
Figure 8.2 Attendance in TICCIT Math Classes 407

LIST OF APPENDICES

(VOLUME II)

Page

Appendix A TICCIT Mathematics Courseware 1
Appendix B TICCIT English Courseware 13
Appendix C Item Classification for Mathematics Posttests 22
Appendix D Essay Topics for English Achievement Tests 29
Appendix E Coverage of English Objective Tests: Item Classifications 31
Appendix F Student Surveys 33
Appendix G Observation of Student Interaction with the TICCIT System 54
Appendix H Registration Data on Section Selection and Demographic Characteristics 60
Appendix I Faculty Attitude Surveys 65
Appendix J Faculty Activity Questionnaire 69
Appendix K Reasons for Section Selection 76
Appendix L Student Demographic Profile 95
Appendix M Course Completion Rates 116
Appendix N Enrollment in Subsequent Terms 145
Appendix O Student Achievement 150
Appendix P Math Posttest Summaries 180
Appendix Q Student Attitudes 195
Appendix R Student Survey Summaries 211
Appendix S Student Activity Summaries 257
Appendix T Faculty Attitude Summaries 275

Summary and Conclusions

Introduction

The computer industry went through a period of tremendous growth between 1960 and 1970. Within education there was a six-fold increase in the number of schools with computers and an even greater increase in college and university expenditures on computers. It became natural to view computers as an emerging technology with major implications for education. However, direct applications of the computer for teaching students accounted for a scant amount of the total computer activity in schools at the start of the 1970's. A major demonstration of the effectiveness of computer-assisted instruction (CAI) was thought to be the catalyst necessary to promote widespread adoption of this new medium.

The MITRE Corporation proposed to develop a small computer system which would be dedicated to supporting instruction within a school. Their TICCIT (Time-shared, Interactive, Computer-Controlled Information Television) program was to bring the cost of computer-assisted instruction down to an affordable level for most schools and thus encourage the mass dissemination of CAI by private industry. In order to achieve a market success, the developers of the TICCIT program chose community colleges as their target audience and mathematics and English courses as their intended subject matter: There had been a dramatic rise in student enrollment at community colleges, and a significant proportion of the total enrollment occurred in relatively few mathematics and English courses. It seemed that resources concentrated in selected courses could affect large numbers of community college students. Under a contract awarded by the National Science Foundation in 1972, the MITRE Corporation undertook the development and demonstration of the TICCIT program at community colleges.

The TICCIT program is a computer-assisted instructional system that combines the strengths of mini-computers with the display capabilities of television receivers. By relying on mini-computers and other equipment already available for purchase commercially, the developers of the TICCIT program took advantage of proven technology and kept total system costs within the financial reach of schools and colleges. The TICCIT systems installed in community colleges can support 128 active terminals and provide instruction equivalent to five full courses in mathematics and English. Options built into the TICCIT system permit students to exercise control over their own instruction: students choose not only a pace at which to work but also a topic for study, a difficulty level appropriate to their performance, and an instructional sequence for learning.

This evaluation covers the results of a demonstration of the TICCIT program at two community colleges. It contrasts the performance of students in classes taught primarily by computer with the performance of similar students from lecture-discussion sections of the same courses. Thus, the outcomes of conventional educational practices served as a relative standard for judging the impact of the TICCIT program on student performance. Comparisons focused on four aspects of student performance: course completion rates, student achievement, student attitudes, and student activities. The evaluation also documents faculty acceptance of the TICCIT program and examines the role of teachers in courses where the primary instructional resource was the computer. Matters related to the cost-effectiveness of the TICCIT program and the technical performance of the computer system were beyond the scope of this evaluation.

Implementation of the TICCIT Program

The TICCIT program became an integral part of the curriculum at two community colleges. Students could register for courses and earn college credits in classes offered on a computer system. The equivalent of three full courses in algebra and two courses in the fundamentals of English composition were available on the TICCIT system. Instructor involvement in these courses varied from direct supervision of all student work to supplementary assistance provided upon student request. In English courses, instructors tended to choose the TICCIT lessons appropriate for their classes and to take an active role in assigning and correcting written exercises; instructors in mathematical courses, where departmental policy set the TICCIT coverage according to curriculum requirements, had responsibility for managing classes sometimes three times the size of usual lecture sections and for advising students on their course progress. All TICCIT courseware adhered to the same instructional design, relying on an hierarchical content structure to organize the subject matter and a rule-example-practice paradigm to suggest strategies for student learning.

Implementing an ambitious and innovative program in schools is in itself a significant accomplishment. It required selecting a sector of education conducive to a market success for computer-assisted instruction, maintaining the interest and commitment of the schools chosen as demonstration sites, and developing complete and independent alternatives to traditional college courses. Because there was rapid growth in student enrollment at community colleges as well as a concentration of that enrollment in a few select courses, the community college seemed to represent a viable market for computer-assisted instruction. By focusing on introductory mathematics and English courses, the TICCIT program could address the basic deficiencies in student preparation prevalent under open admissions at community colleges and offer a replacement for one-fifth of a college's traditional curriculum. The potential existed for a cost-effective application of computers to education that would rekindle commercial interest in providing such services.

The choice of particular community colleges to participate in the project was as carefully planned as the selection of an appropriate market. Since the installation of a new computer system and the introduction of a different curriculum program might initially demand heavy external support, the community colleges had to be in close geographical proximity to the developers. The colleges also had to be able to accommodate the full demonstration as shown by the physical space available for the computer system and student carrels, a curriculum structure parallel to the target courses in the TICCIT program, an enrollment in candidate courses high enough to justify heavy use of all 128 terminals, and a student population similar to the national norms in their characteristics. The developers of the TICCIT program sought and found two community colleges suitable to serve as exemplary demonstration sites in the evaluation.

To insure the smooth and orderly transition of the TICCIT program into the college curriculum the developers adopted several specific mechanisms. Notable among these were: the appointment of local project directors at the colleges and of a central agent responsible for college liaison for the developers; the establishment of a committee with senior representatives of each participant to oversee the project; the development of an implementation plan with specific details on the preparation, installation and operation of TICCIT systems at community colleges; and the participation of community college instructors in developing content specifications for the TICCIT courseware. Each of these steps helped to make the community colleges active participants in project administration and planning.

In order to develop a curriculum equivalent to five full community college courses, the developers of the TICCIT courseware took a systematic approach to the design and production of curriculum materials. Each component of the TICCIT curriculum, regardless of content coverage, adhered to the same basic instructional design. That design depended heavily on maps, similar to learning hierarchies, to lend structure to the subject matter. A series of three maps depicting successively finer levels of detail in the subject matter charted the content coverage of TICCIT courseware. Learner control became available at the finest level of detail, the segment. Each segment contained a rule along with examples and practice problems illustrating the application of that rule. Through options built into the TICCIT system a student could exercise control over the sequence, difficulty level and frequency of rule and instance displays.

The uniform nature of this instructional design across the TICCIT courseware invited the application of a single production model for the entire curriculum. The courseware developers assembled production teams including members with different specialty skills, and they defined a production process specifying the flow of the curriculum along work stations. This approach to curriculum development was meant to facilitate the rapid production of high quality courseware. It did encourage contributions from persons with different fields of expertise, and it did result in the completion of a curriculum comparable in coverage to five full courses. But there were numerous changes to the original production model along the way to these accomplishments. Some became necessary because courseware production took place concomitantly with development of the computer system. Others occurred because the production model was too rigid for adapting easily to schedule demands and work styles.

The evaluation of the TICCIT program involved over 5,000 students in nearly 200 sections of target courses. At least one academic term of college exposure to a particular course on the TICCIT system always preceded our collection of data on program impact. This period of adjustment enabled the colleges to gain experience with the TICCIT program and permitted us to conduct field trials of the instruments and procedures for the evaluation. For mathematics courses the demonstration phase of the project began with the fall term of the 1975-76 academic year; it commenced with the start of the 1976 calendar year for English courses. In general there were academic terms of data collection on program results for each target course.

Results and Discussion

Course Completion Rates. The impact of the TICCIT program on course completion rates, defined as the proportion of students enrolled for a course who later fulfill the course's requirements and receive grades with credit, was negative in every case save one. Of the 17 analyses conducted for target courses within terms, 13 led to statistically significant and negative estimates of treatment effects. The average completion rate for mathematics courses was 16% for TICCIT classes (i.e., 16 students of every 100 enrolled for the course received a grade with credit within an academic term) in contrast to an average of 50% for lecture sections. Figures for English courses showed an average completion rate of 55% for TICCIT classes and 66% for lecture-discussion sections. It appears clear that the TICCIT program had a detrimental effect on the likelihood that a student would complete the college requirements for course credit within an academic term. Even when students pursued their studies on the TICCIT system across terms, their likelihood of completing a course did not improve.

To what should we attribute these results? It is common for developers to counter negative findings with qualifications about the status of their product at the time of its evaluation. System reliability or an incomplete curricular program, for example, might account for these negative findings. But the completion results were consistent across academic terms as the TICCIT system reached a high reliability in its college operations. Results were also consistent across courses, so faults at just particular points in the TICCIT curriculum seem an inadequate explanation for the negative effects. Nor is the problem the same as attrition: students tended to remain in their classes and simply failed to fulfill the requirements for receipt of a grade with course credit.

The reasons behind the lower completion rates observed in TICCIT classes seem to stem from fundamental concepts of the program itself. Through learner control the TICCIT program shifted the emphasis in instruction from the computer teaching to the student learning. Students had to assume responsibility for their own learning. Other instructional conditions that allowed students to set their own pace for learning had also resulted in lower completion rates than lecture sections. This held for the audiotutorial system that preceded the TICCIT program at one demonstration site and the programmed instruction that competed with the TICCIT program at a second demonstration site. The major factor behind the effects of the TICCIT program on course completion is probably a generic problem. Programs that allow each student to proceed at his or her own pace risk losing students unable to manage their own instruction.

The analyses for course completion rates also call into question one of the initial premises of the TICCIT project: That community colleges constitute an appropriate audience for the TICCIT program. The community college, like other sectors of education, doubtless has use for effective curricula in introductory mathematics and the fundamentals of English composition. Enrollment at community colleges continues to grow even as it declines elsewhere. It is an appropriate target for a market success, but the diversity of students at community colleges also makes it difficult for any curriculum to anticipate and satisfy the range of student abilities and needs. Only those students with a strong background in mathematics actually completed algebra courses under the TICCIT program, and students with a stronger initial grasp of English fundamentals stood a higher probability of completing English courses on the TICCIT system than did students weaker in their entrance ability. Perhaps with a less heterogeneous student population the course completion rates of the TICCIT program would improve.

Student Achievement. The analyses conducted for student achievement again indicated significant effects due to the TICCIT program but these estimates of treatment effects were positive. Studied across academic terms in order to increase sample size, the achievement results in mathematics courses revealed a significant positive effect in five of six cases. These positive TICCIT effects held regardless of the statistical adjustments made in attempting to compensate for non-equivalent groups. Students completing a mathematics course on the TICCIT system had higher posttest scores than comparable students from lecture sections. Estimates of the size of significant TICCIT effects indicated an increase of better than ten percent over the achievement results attained with conventional teaching practices. The results from English courses were not as dramatic, since most significant effects could be attributed to the particular circumstances of the demonstration rather than to the TICCIT program. Still, there was one course in the fundamentals of English composition in which a significant, positive effect was replicated across academic terms. That effect amounted to a five percent increment in student achievement.

These improvements in student achievement under the TICCIT program reflect the posttest performance of students who completed courses on the computer system. Estimates of treatment effects represent the difference between the actual posttest scores of students in TICCIT classes and the probable scores of those same students had they instead been in lecture-discussion classes. Students usually took the posttests as their final examination in a course upon satisfying all other course requirements. Thus, the achievement gains reported for mathematics and English courses apply only to those students capable of completing a course under the TICCIT program. Given the course completion rates in TICCIT classes, it should be clear that this student population is really a subgroup of all students initially enrolled for a course on the TICCIT system and much smaller than the parallel population of students from lecture-discussion sections of the same courses. In two mathematics courses the treatment effects applied to an even more specific student population, namely students completing algebra courses under the TICCIT program in the evening division of the college. It would be inappropriate to infer that the TICCIT program improves achievement for all students.

Particularly those students stronger in their prior familiarity with the subject matter benefited from taking a course on the TICCIT system. From pretest scores in mathematics courses it became evident that students weak in entrance ability failed to satisfy course requirements in TICCIT classes while students strong in prior familiarity completed courses under the TICCIT program and did well on posttests. Similarly, the analyses for completion rates and student achievement in English courses indicated that the impact of the TICCIT program on these aspects of student performance depended on a student's entrance ability. The negative estimates of treatment effects in English courses grew larger as students' pretest scores declined. Since students with less prior familiarity of the subject matter tend to require greater instructional support, it appears reasonable to conclude that the TICCIT program provided instructional support sufficient for students of strong entrance ability but inadequate for others.

Subject to interactions involving different treatment effects dependent on students' prior familiarity with the subject matter, the TICCIT program succeeded in improving achievement results. Students who completed courses under the TICCIT program generally attained higher posttest scores than similar students in lecture-discussion classes. Because posttest scores included only those items that reflected objectives common to both the TICCIT program and the regular curriculum, and because the statistical analyses took demographic characteristics (e.g., age, sex, employment status) as well as prior knowledge of the subject matter into consideration whenever sample size permitted, these achievement results do seem to represent the positive impact of the TICCIT program itself. Yet the treatment effects on student achievement arose among students with a stronger initial grasp of the subject matter. While such students may constitute a small percentage of the community college's total enrollment, especially for introductory courses in mathematics, they might be a majority of the learners in another context. At industrial or educational institutions which screen and select applicants on a competitive basis, the TICCIT program could result in uniform positive effects on student achievement.

Student Attitudes. The pattern of results in the evaluation of student attitudes clearly demonstrated that affective reactions to the TICCIT program depended on the manner of its use. While the estimated treatment effects had been consistently negative for course completion rates and generally positive for student achievement, those for student attitudes changed in direction and significance as the context of TICCIT classes changed. This aspect of student performance highlights the importance of the conditions under which applications of computer-assisted instruction take place, especially the role played by the teacher in facilitating student learning on computers. On the whole, students in TICCIT classes reacted less favorably to their mathematics course than did students of comparable ability in lecture sections. English courses in which each instructor decided on the extent of student exposure to the TICCIT system also showed negative treatment effects on student attitudes. However, a course in the fundamentals of English composition had significant, positive attitude results. In this course the TICCIT program was the primary instructional resource, but instructors took an active role in explaining the subject matter, reviewing written assignments and conducting small group discussions.

The influence of the context of a course on student attitudes was particularly evident from scores on attitude scales established through factor analyses. Students viewed a mathematics course itself and the fit of instruction in the course to their own needs nearly as favorably in TICCIT classes as in lecture sections. The reasons for students' less positive reactions to mathematics courses under the TICCIT program seemed to lie in their perceptions of the individual attention devoted to them and their judgments of the usefulness of specific system features. When the student-teacher ratio in TICCIT classes was higher than that in lecture sections of mathematics courses, students reported receiving less individual attention in TICCIT classes. The TICCIT program had not alleviated a student's need for the assistance of an instructor and perhaps had generated a greater demand for individual attention. The results of the attitude scale representing students' reactions to specific features of the TICCIT system support this conclusion: instructors provided better explanations of difficult material than did the HELP feature on the TICCIT system and gave clearer presentations of mathematical concepts than the RULE feature. In English courses, which represented a combination of regular classroom sessions and computer-assisted instruction, there were significant, negative treatment effects on every attitude scale. To students, a mixture of learning on the computer and teaching in a classroom may be like taking a course under two instructors with different approaches to the subject matter. The TICCIT program had been intended as a curriculum appropriate for intact courses and may best support such applications.

The exception to these less favorable attitudes among students in TICCIT classes occurred in a course on the fundamentals of grammar and written expression. Students in TICCIT classes of this course expressed a greater degree of personal satisfaction with their course and reported a greater amount of individual attention had been devoted to them. Such attitudes stood behind the significant, positive treatment effects observed in this course. The course format apparently drew on the strengths of the TICCIT program in providing practice exercises, of the instructors in elaborating on difficult material and motivating student work, and of group discussions in promoting personal interactions. The results were positive student attitudes and higher posttest performance.

Computer-assisted instruction by itself neither guarantees favorable student attitudes nor meets all student needs for further elaboration and clarification of the subject matter. Especially with a student population as heterogeneous as that at community colleges it may be impractical to attempt developing a tutorial computer application capable of meeting the needs of all students. Instructors must be available for explaining what students find difficult to understand. Moreover, a computer system that supports the equivalent of full college courses may relieve instructors of their usual duties but it also generates new demands which preclude any dramatic increase in normal student-teacher ratios. The TICCIT program has shown that computer-assisted instruction can, under proper conditions, both facilitate student learning and promote favorable student attitudes.

Student Activities. What differences occurred in student self-reports about their activities seemed a natural consequence of the instructional conditions for a course. Typically exposure to a course on the TICCIT system encouraged a percentage of students to take further courses in the subject matter roughly equal to the percentage found in lecture-discussion sections. Course experiences made a job related to the subject matter seem more attractive to like percentages of students in each instructional condition. Perhaps unexpected was the fact that students reported as much interpersonal contact in TICCIT classes as in lecture-discussion sections. In both conditions discussions of course questions with fellow students was the most frequent type of contact. These data tend to counter arguments about the impersonal nature of computer applications in education. Differences in student activities arose in the time spent on course studies. Across courses, students in TICCIT classes spent most of their study time working on the TICCIT system while students in lecture sections reported most of their time given to working on homework assignments. So much time was devoted to homework assignments in lecture sections of mathematics courses that students in TICCIT classes spent less total time on their course studies. Since English courses on the TICCIT system still involved written assignments and often included small group discussions or regular classroom sessions, students in TICCIT classes for an English course reported spending more time on their course studies than students in lecture-discussion sections.

Systematic observations of student interactions with the TICCIT system revealed behavior consistent with other results. Less than one-half of the sample of students randomly drawn for observation remained in their mathematics course throughout the academic term. This decrease in sample size reflected a tendency among students in TICCIT classes to neglect their course studies. Indeed, the most obvious trait shared by students completing an introductory algebra course under the TICCIT program, aside from pretest scores higher than their classmates, was regular attendance. This suggests that monitoring attendance closely could improve course completion rates. Contrary to what might be expected if learning strategies improved as students gained experience with the TICCIT system, or if certain strategies gave students a higher probability of success (i.e., course completion), there were no remarkable differences in students' use of the TICCIT system either across observation cycles or between students with complete sets of observations and others with fewer observations. Most often, there was no sequence observed for students' use of the learner control features available at the TICCIT system, primarily due to the low incidence of student referral to rule statements and examples. Students instead concentrated on practice problems. While the rules and the examples of their application might easily be presented in another format, practice problems called the computer capabilities inherent to the TICCIT system into play. It was in solving practice problems that students received feedback both for confirming correct responses and for providing remediation for incorrect responses. The usefulness of practice problems evident from student choice of this feature fits well in the context of other outcomes. It is consistent with the positive TICCIT effects on student achievement, specifically those regarding the solution of routine problems in mathematics and, as shown in the objective test of writing skills, the identification and correction of sentence errors in English composition. Also, PRACTICE was the one system feature that received high ratings by students both in comparison to its closest counterpart in lecture classes (i.e., homework assignments) and contrasted with ratings of other components of TICCIT's learner control. The practice problem appeared to be the cornerstone of the TICCIT system.

The TICCIT system maintained data on the amount of time spent by students on the computer system. The average amount of time on-line for all students exceed 20 hours in each course, and for students with posttests (i.e., those students who completed courses on the TICCIT system) the average time on-line was above 30 hours and sometimes nearly 40 hours per academic term. These latter figures for students with posttests indicate attendance equivalent to three and sometimes over four class periods per week. That students in English courses spent as much time on-line as students in mathematics courses, despite the additional written assignments and classroom meetings or small group discussions in English courses, seemed to suggest the influence of instructor contacts on student attendance. With regular instructor contacts outside of sessions on the TICCIT system, students perhaps felt responsible for their own learning and answerable to a specific faculty member.

Teacher Role. Its developers had anticipated that the TICCIT program would change the nature of a teacher's duties and responsibilities. As a mainline application of computer-assisted instruction, the TICCIT program would become the primary resource for student learning while instructors gave further assistance upon student request. There were indeed marked differences between the activities reported by instructors in TICCIT classes and those reported by instructors in lecture-discussion sections. Direct observations of instructors' activities in TICCIT classes confirmed the description given by instructors themselves and provided greater detail about the tasks performed by teachers under the TICCIT program.

The TICCIT program nearly eliminated the burden of preparatory work and instead enabled instructors to devote a considerable proportion of their time to individual students. Instructors with lecture-discussion sections of target courses usually spent one-fourth of their time preparing lectures and developing student assignments and tests. There was no such demand in TICCIT classes. Furthermore, lecture sections of mathematics courses required one-half of an instructor's time for conducting classroom sessions while didactic work in TICCIT classes took only one-fourth of an instructor's time. This reduction in the time spent on usual duties was offset by increases in the amount of time spent on other tasks. Specifically, instructors in TICCIT classes devoted roughly one-third of their time to counseling students on content questions;

the same activity accounted for less than one-tenth of the duties performed by teachers in lecture sections. Instructors for mathematics courses under the TICCIT program spent another third of their time on monitoring student performance on mastery tests.

Responding to student questions about the subject matter and monitoring student performance on mastery tests occupied the bulk of instructors' time in TICCIT classes. These activities may signify the difficulty encountered by some students in learning on the TICCIT system and, therefore, conform with the course completion rates found under the TICCIT program. Such extensive instructor contact with individual students may also indicate the assistance which enabled other students both to complete courses on the TICCIT system and to attain higher scores on achievement posttests. These alternative interpretations of instructor activities suggest a basic dilemma: Did the TICCIT program relieve instructors of routine duties and permit them to make better use of their time, or did it generate new demands that prevented any freedom of choice in allocating their time to activities? Judging from the attitudes expressed by students in TICCIT classes, it would seem that instructors planned their own activities in English courses but reacted to the needs of the situation in mathematics courses.

Faculty Acceptance. A survey conducted prior to the installation of TICCIT systems at the community colleges identified the major dimensions behind faculty attitudes toward educational practices and computer-assisted instruction. The clearest and most prominent dimension behind faculty attitudes toward educational practices was a focus on the interests of the student. Faculty seemed to base their responses on what they considered best for students, and they certainly believed in the importance of personal interactions in student learning. Other dimensions reflected an emphasis on the subject matter of a course, a college's receptivity to innovation, and incentives for student work. On the whole, faculty responses to statements about educational practices indicated attitudes supportive of the premises inherent to the design of the TICCIT program. In contrast to the four factors found to underlie faculty beliefs about educational practices, two factors sufficed for describing faculty attitudes toward computer-assisted instruction. These dimensions simply reflected general attitudes toward CAI and familiarity with computers. The majority of faculty members lacked any prior experience with computers and thus had no practical basis for differentiating among the statements about computer-assisted instruction. Most often, faculty indicated that they were unsure about the probable impact and significance of computer-assisted instruction. Certainly there was an openness to the concepts behind the TICCIT program and an absence of any apparent school resistance to either innovative projects or instructional technology.

Nearly two years later there was another survey of faculty attitudes that explicitly dealt with reactions to the TICCIT program. The five dimensions found on this survey reflected global judgments of the TICCIT program, opinions about the management of instruction in TICCIT classes, perceptions of limitations in the TICCIT program, beliefs about the teacher's role in TICCIT classes, and familiarity with computers. The most frequent response to statements calling for a global judgment of the TICCIT program was "not sure" despite several academic terms of experience with the TICCIT system. Faculty were unsure of whether or not the TICCIT program constituted a significant development in education just as they had earlier been unsure about CAI in general. They had thought that CAI would make students active in their own learning and that it would tailor instruction to the individual student; the TICCIT program met these expectations. Prior to the implementation of the TICCIT program at the colleges, faculty generally believed that computer-assisted instruction would relieve instructors of routine duties and enable them to make better use of their capabilities. After several academic terms of experience with the TICCIT system, faculty expressed uncertainty that the TICCIT program had affected instructor duties in such ways. Instructors had become less certain that computer-assisted instruction, particularly the TICCIT program, would benefit them in fulfilling their instructional responsibilities. Moreover, those instructors closely associated with the TICCIT project often reacted to the program less favorably than their colleagues in other departments.

Implications

Applications of the TICCIT Program. The TICCIT program had a significant, positive impact on student performance. This held under mainline applications in which the computer became the primary resource for student learning. Other applications combining regular classroom sessions and computer-assisted instruction showed course completion rates, student achievement and student attitudes generally lower than would be the case in lecture-discussion sections. The TICCIT program had been intended to support intact courses and best served that purpose. However, instructors played a critical role in facilitating student learning on the TICCIT system. Students' attitudes toward courses under the TICCIT program surpassed those of students in traditional classes only when instructors elaborated on the subject matter by explaining difficult material and supplementing the computer curriculum with small group discussion. The TICCIT program did not lessen a student's need for the assistance of an instructor; it only changed the nature of the tasks performed by teachers.

Despite the improved student achievement and sometimes favorable student attitudes made possible by the TICCIT program, there were dramatic decreases in course completion rates. This may reflect a generic problem with self-paced instruction in that students unable to manage their own learning fail to satisfy course requirements. Such students constitute a sizeable percentage of the total enrollment at community colleges. If the TICCIT program continues at community colleges, there should be careful monitoring of student attendance and explicit incentives for steady course progress. Regular contact with instructors outside of sessions on the TICCIT system and small group discussions may also provide additional student motivation and thereby improve course completion rates.

The results of this evaluation suggest that the TICCIT program may be inappropriate for community colleges. Only those students strong in their initial familiarity with the subject matter benefited substantially from courses offered under the TICCIT program. Other students either failed to complete courses on the TICCIT system or derived less benefit from exposure to the program. The strongest argument for a continuation of applications at community colleges would be a counterexample to the course completion rates observed in this evaluation. At institutions with a more select and less heterogeneous student population or with compulsory attendance in instructional programs, the TICCIT program could lead to uniform, positive results.

Adoption of Computer-Assisted Instruction. The TICCIT program has confirmed the potential of computer-assisted instruction as an effective resource in student learning. Students in TICCIT classes attained posttest scores higher than those of similar students in classes taught by traditional practices. These increments in student achievement amounted to ten percent improvements in mathematics courses and five percent in English courses. Under the proper conditions, the TICCIT program also led to student attitudes more favorable than those of students in lecture-discussion classes. This demonstration provides further evidence for advocating school adoption of computer-assisted instruction. But widespread school adoption of computer-assisted instruction and expectations of significant increases in school productivity would be premature.

Computer-assisted instruction by itself guarantees no magical solutions to the problems faced in education. Results will depend on the instructional design of the curriculum materials, on the manner of implementation, on the nature of the student population, and on the role played by teachers. It is advisable that computer applications in education start with a recognition of the factors involved in the instructional process and seek to use each to its fullest potential. The computer alone is simply an alternative mechanism for the delivery of instruction. Its strengths lie in its capabilities for providing feedback on student performance and its potential for engaging students as active participants in their own learning.

Chapter 1

Introduction

In 1971 the National Science Foundation awarded a contract to the MITRE Corporation to develop and demonstrate the TICCIT program. This program uses mini-computers and modified television receivers as the heart of a computer-assisted instructional system, thus its acronym: Time-shared, Interactive, Computer-Controlled Information Television. At first the CAI Laboratory at the University of Texas and later the Institute for Computer Uses in Education at Brigham Young University assumed responsibility for the design and production of curricular materials for the TICCIT system. The TICCIT project began with the combined talents of engineers and educators. It followed, therefore, that the system join available technology components and innovative teaching strategies together so as to form a complete program tailored for the delivery of instruction and the promotion of student learning on an individual basis.

The TICCIT project overcame significant obstacles in technical and instructional design. Now it puts computer-assisted instruction for entire courses in precalculus mathematics and English composition within the financial reach of colleges, at least in terms of system purchase costs. Whether the educational outcomes probable with the TICCIT program justify such a purchase is a difficult cost-benefit issue that ultimately reduces to subjective judgments. Here we provide information on the educational impact of the TICCIT program. This first chapter reviews the general conditions which led to the project, points to several key features that attracted attention to the project, and then presents a description of the TICCIT system. It concludes with statements of the developers' goals and evaluator's purposes.

1.1 Background

The computer industry went through a period of tremendous growth between 1960 and 1970. During that period the number of schools with computers increased from approximately 200 to over 1,250 (Comstock, 1972a). Expenditures on computers took a similar jump. Just within higher education expenditures went from $49 million in 1962-63 to $352 million in 1968-69 (Comstock, 1972a). Given such phenomenal growth it was natural to view computers as the emerging technology with major implications for educational practice.

Indeed there were optimistic predictions for a revolution within education and aggressive efforts by the computer industry to capture this market for new equipment. A report by the Carnegie Commission on Higher Education (Kerr, 1972) estimated that the role of instructional technology in higher education would expand through research, administration, and libraries until there was widespread use for instruction after the year 2000. Major computer firms began new divisions devoted to instructional systems. Hardware configurations and support packages specifically tailored for education appeared on the market.

Research and development struggled to keep pace with the computer explosion in education. Catalogs listed numerous computer programs written for specific applications (e.g., Lekan, 1971). The level of activity and interest in such computer applications prompted the formation of information exchanges to spread the word about available programs and encourage dissemination (e.g., ENTELEK, 1971). There was a parallel increase in the literature about computer applications for instruction (e.g., Razik, 1971), most of it descriptive or exploratory in nature.

The computer as a resource had taken hold in education. Even closer to today forecasts still indicate a growth rate above 15 percent annually for our expenditures on computer hardware (Rockart & Scott Morton, 1975). Again, the magnitude of these investments would suggest a substantial impact upon the educational process.

Certainly the computer has become an invaluable tool in educational research and school administration. Instruction about computers, how to write programs or design systems for example, has become commonplace in our schools and colleges. But direct applications of the computer to transmit instruction, to convey information to students, accounted for a scant amount of the total computer activity in schools at the start of the 1970s (Comstock, 1972a). This was true despite the potential of the computer as a medium for meeting the needs of individual students and reshaping the learning process (see Bushnell & Allen, 1967; Coulson, 1970).

There were illustrations of successful applications of the computer for instruction. These ranged from programs in arithmetic for elementary schools (Suppes & Morningstar, 1969) to projects in physics for college students (Kromhout, Edwards, & Schwartz, 1969). Rather than give conclusive evidence on the results from computer-assisted instruction (CAI) and thus promote widespread use, such exemplary applications seemed to strengthen arguments about the potential of the computer as an instructional resource. Certain studies did suggest significant differences in favor of a CAI supplement to traditional instruction (see Feldhusen & Szabo, 1969; Vinsonhaler & Bass, 1972 for brief reviews). Some demonstrated an improvement in teaching efficiency since students took less time to learn a given amount of material (e.g., Bitzer & Boudreaux, 1969; Ford, Slough, & Hurlock, 1972). Other comparisons of achievement results between regular classrooms and experimental classes supplemented with CAI showed a positive effect for CAI (e.g., Butler, 1969; Culp & Castleberry, 1971). Most studies reported, in anecdotal or descriptive form, favorable student reactions to CAI (see King, 1975 for a review). Still, schools had not adopted CAI on a grand scale.

A variety of factors might be cited as contributing to this resistance, or at least reluctance, to adopt CAI. Advocates of instructional technology tended to list a few major problems: inadequate federal resources for CAI research and development; teacher resistance to such innovations; lack of commitment from the commercial sector; and the need for a major demonstration with national prominence as an impetus toward the adoption of CAI (e.g., Anastasio & Morgan, 1972; Armsey & Dahl, 1973; Holland & Hawkins, 1972). Cost must be considered as another major factor inhibiting the use of CAI (Judd, 1971). Perhaps even the absence of an independent evaluation played a role in schools' hesitation to invest in instruction with computers.

The rapid growth of the computer as an educational resource and schools' reluctance to adopt CAI may seem contradictory. But most expenditures on computers were confined to administrative data processing, research applications or instruction about programming and hardware design. It is important to reiterate the fact that only a small proportion of the dollars spent on computers went to direct instructional applications in which the computer served as the mechanism that did the teaching. Despite an expanding market for the computer within education and a growing body of evidence on the benefits of instruction with computers, schools had yet to adopt CAI. To a great extent, the CAI activity that did occur was limited to what the federal government supported.

The MITRE Corporation proposed to break this log jam in the flow of CAI to schools. Their TICCIT (Time-shared, Interactive, Computer-Controlled Information Television) system was to be a small, cost-effective alternative to the larger CAI systems then planned (Stetton, 1971). It would bring the cost of CAI down to an affordable level for most schools and thus encourage the mass dissemination of CAI through private industry. There was considerable support for the demonstration of such a system in order to prove the merits of computer-assisted instruction for teaching and reduce per student costs in a tight economy.

1.2 Key Features of the TICCIT Project

As a nonprofit organization MITRE sought and received a federal grant to elaborate on the design of the TICCIT system. This grant followed an already substantial investment of MITRE's own funds to study the economic feasibility of CAI. In 1971 MITRE, in conjunction with the CAI Laboratory at the University of Texas, began to specify the design elements necessary for a cost-effective application of CAI. Their initial work culminated in a proposal to install the TICCIT system in schools and demonstrate its impact on the educational process.

There were several unique features in the plans for the TICCIT project. At least five points, when taken together, distinguished the TICCIT program from other CAI applications. These might be restated here as: (1) market success; (2) local facility; (3) available hardware; (4) learner control; and (5) "mainline" instruction. None of these concepts can convey much about TICCIT without some explanation of what each implies about the rationale for the TICCIT project.

Market Success. From its inception the TICCIT program held a market success as its primary goal (see MITRE, 1972). It was an explicit attempt to create a supply-demand situation conducive to a commercial success for CAI. The developers argued that low cost, high quality, or technical sophistication would not guarantee school adoption of CAI. Of course these would be necessary conditions for a market success, but not in themselves sufficient. The TICCIT program was to serve as a catalyst in the mass dissemination of CAI through its systematic application to educational needs. Commercial vendors of computers and publishers of instructional materials had forsaken the potential market for CAI. Major computer firms had embarked on ambitious marketing programs in the 1960's only to abandon instructional applications as a result of their quite limited success. TICCIT's developers hoped to rekindle their interest with a strong example of a market success. Schools in search of a CAI system would provide a powerful incentive for private industry to reenter the education market.

Local Facility. Just as market success represented a bold goal, MITRE also took a distinctive approach to the economics of CAI. The TICCIT system was to be a small, local facility built around a marriage of mini-computers and television technology. It would be small enough for a school of modest size (perhaps 1200 students) to purchase and install its own intact system. Such a local facility provided an alternative to the large-scale system for CAI then under development (i.e., Bitzer & Skaperdas, 1971). Arguments about the relative advantages of small and large computer systems continue today since each type has its strengths. Here it is sufficient to note that the TICCIT project stood on one side of that small-large continuum for system size.

Available Hardware. Costs had to be kept low if a school were to be able to afford a TICCIT system. MITRE advocated the use of available hardware components in order to reduce CAI costs to such a level. The TICCIT system combined computers already on the market with proven television technology. Its uniqueness stemmed from the total system design rather than the characteristics of a single part. Indeed its components could be purchased "off-the-shelf" and then, with minor modifications, assembled to form the basis for a TICCIT system. Yet a system constructed in this manner could display a rich variety of instructional materials as well as process students' responses to questions and follow their directions for an appropriate teaching strategy.

Learner Control. The capability to accept students' directions for teaching was the result of an innovative approach to instructional design. Through options built into the TICCIT system a student could exercise control over his own instruction. Each student could choose a topic for study, a difficulty level at which to work, and an instructional sequence for his or her learning. The menu of possible student choices defined the limits of learner control over difficulty and sequence, and the structure given to the subject matter restricted the range of topic selections. This approach to learner control combined our knowledge about how to present material (Merrill & Boutwell, 1973) with that on how to structure content (Gagne, 1970). It also gave recognition to differences among students and attempted to meet the needs of individual students through flexibility in teaching method.

Mainline Instruction. The concept of "mainline" instruction was a significant departure from the familiar use of computers as a supplement to classroom instruction. Rather than serve as an adjunctive resource for the teacher, the TICCIT program itself was to be the primary source for instruction. It would give students an opportunity to study at separate rates of progress and free teachers for concentrated work with individual students. In effect, the TICCIT program would also make it possible for school administrators to increase the student-teacher ratio and thus reduce the labor-intensive aspect of costs in education.

This last distinctive feature of the TICCIT program begins to touch on the manner of application advocated by the program's developers. While other features of the computer system certainly contributed to its potential for instruction, two points about the use of the TICCIT system deserve mention along with the key features of the program. These involve MITRE's choice of the community college as an appropriate level of education for a demonstration of the TICCIT program, and their decision about which curricular materials belonged on the TICCIT system.

MITRE sought to avoid school resistance to CAI and therefore chose community colleges as an appropriate test case for market success. Community colleges had to meet the diverse needs of the local population as well as the demands of increased enrollment (see Bushnell, 1973). Their commitment to student service together with growth in enrollment under open admissions made community colleges receptive to such changes as the TICCIT program. In addition this segment of higher education seemed to be lowest in the proportion of schools with access to CAI (Comstock, 1972b).

Just as the choice of the community college was the result of careful thought about a potential market, so the selection of subject matter to be taught on the TICCIT system hinged on economic and educational considerations. MITRE estimated that as much as one-fifth of a student's program of study took place in remedial or introductory courses offered in the mathematics and English departments. This meant that a small number of courses represented a major part of the community college's curriculum in terms of student enrollment. Further, there was a pronounced need for improved instruction in algebra and writing skills. A large percentage of students do not complete their introductory algebra courses, and it has become difficult for community colleges to deal with the variety and extent of student deficiencies in writing. Mathematics and English were selected as the target courses for the demonstration of the TICCIT program.

Its developers believed that the TICCIT program had the potential for substantial impact on instruction in community colleges, particularly instruction in algebra and writing. In order to demonstrate this impact MITRE proposed the installation of TICCIT systems at two test sites. The Alexandria Campus of the Northern Virginia Community College and Phoenix College of the Maricopa County Community College District agreed to serve as field locations for the demonstration.

1.3 Description of the TICCIT System

The concept of a system begins to describe the products as well as the activities of the TICCIT project. In a traditional sense a computer system for instruction has hardware, software and curricular materials or courseware. The TICCIT program also had other subsystems. Its procedures for developing curricular materials, plans for installing and operating computers to do college teaching, and manuals for introducing faculty to TICCIT were as much parts of the overall system as the computers themselves. Still, an elaboration of these activities comes later (see Chapter 3: Implementation of the TICCIT Program) and here we concentrate on the familiar components of a CAI system.

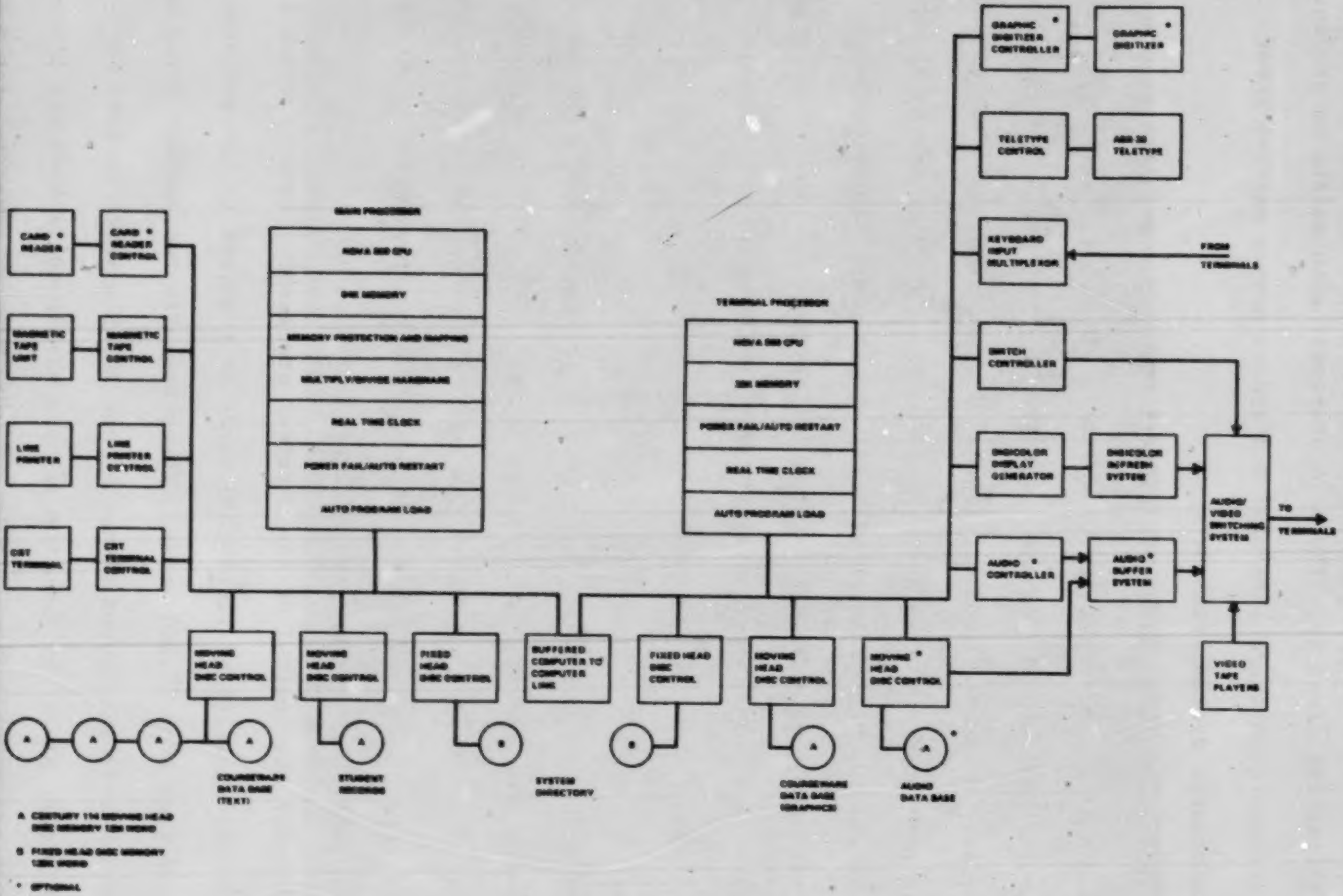
The TICCIT instructional system as described below is the same as that intended for use in community colleges. Other configurations exist for military training and special education (see Rappaport & Olenbush, 1975) but these were not part of the MITRE proposal for a field demonstration and came after the initial work for that demonstration had begun. The information presented here is taken primarily from the MITRE Corporation's own description, An Overview of the TICCIT Program (1976). Further details about the TICCIT system, especially those components designed specifically for the TICCIT project, can be found in that report.

1.3.a Hardware

The hardware for the TICCIT system is what a visitor to a site would see: physical devices that look like grey boxes in assorted sizes and television sets with keyboards similar to those on electric typewriters. Actually these are the computers and their peripheral equipment, including the subsystems built for the TICCIT project and the terminal stations at which students learn. Much of the equipment is available for purchase commercially such as the two Nova 800 computers from Data General or the Century 114 disc drives. Other pieces of hardware had to be adapted for the TICCIT system, for example the color television sets that function under computer control. A third category of equipment had to be constructed for specific needs peculiar to the TICCIT system, like the devices that translate digital messages from the computer into video displays for the color televisions.

Figure 1.1 presents a schematic diagram of the TICCIT computer system. The system revolves around two mini-computers and their associated devices for storage and input-output. This basis for the system is off-the-shelf technology that is readily available for purchase. The digicolor system, audio system and graphic digitizer represent unique hardware elements built to satisfy specific needs. The terminals, absent from the diagram but certainly an essential part of the whole system, constitute the most visible part of the system since it is where the student interacts with the computer.

Computers and Peripherals. The TICCIT system has a dual processor. One mini-computer serves as the main processor and another as the terminal processor. The main processor has a larger memory (65,536 words of core storage) and does the bulk of the work. It uses the courseware data base to assemble


CARD * READER
CARD * READER CONTROL
MAGNETIC TAPE UNIT
MAGNETIC TAPE CONTROL
LINE PRINTER
LINE PRINTER CONTROL
CRT TERMINAL
CRT TERMINAL CONTROL
MAIN PROCESSOR
NOVA 800 CPU
64K MEMORY
MEMORY PROTECTION AND MAPPING
MULTIPLY/DIVIDE HARDWARE
REAL TIME CLOCK
POWER FAIL/AUTO RESTART
AUTO PROGRAM LOAD
TERMINAL PROCESSOR
NOVA 800 CPU
32K MEMORY
POWER FAIL/AUTO RESTART
REAL TIME CLOCK
AUTO PROGRAM LOAD
GRAPHIC DIGITIZER CONTROLLER *
GRAPHIC DIGITIZER *
TELETYPE CONTROL
ASR 33 TELETYPE
KEYBOARD INPUT MULTIPLEXOR
FROM TERMINALS
SWITCH CONTROLLER
DIGICOLOR DISPLAY GENERATOR
DIGICOLOR REFRESH SYSTEM
AUDIO/ VIDEO SWITCHING SYSTEM
TO TERMINALS
AUDIO * CONTROLLER
AUDIO * BUFFER SYSTEM
VIDEO TAPE PLAYERS
MOVING HEAD DISC CONTROL
MOVING HEAD DISC CONTROL
FIXED HEAD DISC CONTROL
BUFFERED COMPUTER TO COMPUTER LINK
FIXED HEAD DISC CONTROL
MOVING HEAD DISC CONTROL
MOVING * HEAD DISC CONTROL
A
A
A
A
A
B
B
A
A *
COURSEWARE DATA BASE (TEXT)
STUDENT RECORDS
SYSTEM DIRECTORY
COURSEWARE DATA BASE (GRAPHICS)
AUDIO DATA BASE
A CENTURY 114 MOVING HEAD DISC MEMORY 12M WORD
B FIXED HEAD DISC MEMORY 128K WORD
* OPTIONAL

TICCIT Computer System

Figure 1.1

textual displays and process students' answers to problems as well as their directions for teaching strategy. The main processor also maintains student records and protects both student records and system memory against power failures or unforeseen system crashes.

In order for the main processor to fulfill these responsibilities the terminal processor has to handle the input-output demands of 128 terminals. The terminal processor receives keyboard entries from the terminals and transfers complete messages over to the main processor. It then feeds back textual displays or generates audio messages and graphic material as directed by the main processor. The terminal processor does little of the actual computation like judging answers, determining sequence, or updating records. Instead it juggles input-output messages for 128 terminals and services them so that it seems as if each terminal has a dedicated communication link with the computers and no other terminal competes for time.

The discs that go along with the processors provide storage for data that correspond to the processors' tasks. Since the main processor forms frames of text and keeps records of students' progress, it has access to disc storage for courseware data as well as student data. Two other moving head discs for the courseware data necessary in generating graphics and constructing audio messages fall under the control of the terminal processor. Each of these five discs has a memory capacity of 12,000,000 words in contrast to the processors' core storage of less than 70,000 words. There are also two smaller fixed head discs: one which stores a system directory and another which buffers keyboard data. The directory gives the location of data within the system and lists valid user identification numbers. Such a memory bank is essential for a CAI system based on mini-computers. With this configuration the TICCIT system holds the textual materials necessary for five full semester courses on three moving head discs. Two additional discs store the data bases for audio and graphics messages.

Besides disc drives the TICCIT system includes a somewhat standard array of peripheral equipment. As shown on the left side of the diagram for the TICCIT computer system (Figure 1.1), there is a card reader, a magnetic tape unit, a line printer, and a console for system operation. These peripherals facilitate courseware development and help fulfill the administrative functions that accompany a mainline CAI system.

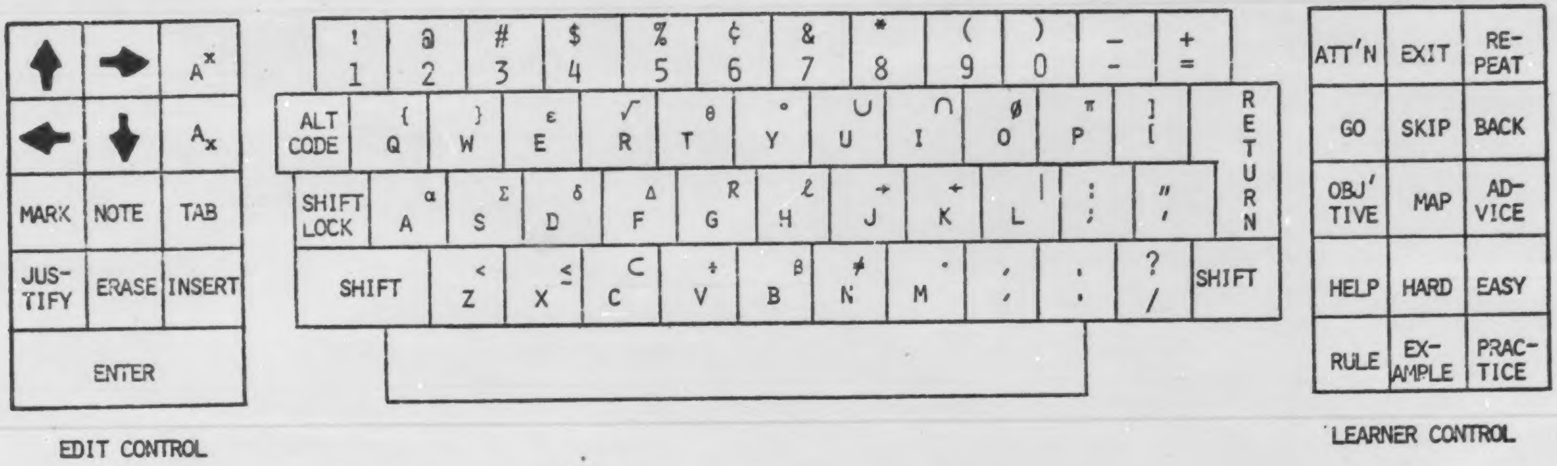
Special Devices. As the first instructional system to combine computer and television technology, the TICCIT program faced some unique problems that required special hardware subsystems. MITRE designed a digicolor system in order to convert digital computer messages to display signals consistent with television receivers. The display generator decodes the computer message and transfers a single frame TV picture over to the video refresh memory. This refresh memory then sends that single picture to its associated TV receiver and continues to repeat the picture so that it appears as a steady display. The refresh memory has a solid-state design with one printed circuit board for luminance and another for color. Of course TV receivers also accept full color videotape signals: the TICCIT system has a set of 20 video cassette tape players which the computer directs, although an operator must perform the manual operations like loading a given tape. Since the digicolor system sends television pictures over coaxial cables, the TICCIT signals can be compatible with normal cable TV reception.

The TICCIT audio system holds about 2 1/2 hours of sentences and phrases recorded as digital information. Each second of these hours is stored as 20,000 bits, thus the need for a large disc memory to serve as the audio data base. Attached to the terminal processor is a digital to analog converter that retrieves audio messages from disc storage via a shift register buffer, and then passes the messages through a switching system to the TV receivers. Another converter handles the reverse process in courseware development: it accepts a continuous voice signal and stores it as binary information. The complete audio system can transmit simultaneous messages to approximately twenty receivers.

A third special subsystem permits the semiautomatic entry of graphics into the courseware data base. This is an optional system component as it facilitates courseware production rather than delivery. The actual production of graphic materials still takes place outside of the TICCIT system, but there is a graphic digitizer that scans artists' work and records it as part of the courseware data base connected to the terminal processor. In the graphics digitizer a modified TV camera scans an artist's drawing and records the luminance and color data for the graphics on that paper. There is an edit program for the graphics source file so an artist can later check the results of the camera's scan and make changes to the actual display frame as necessary. With the projection for over 10,000 pieces of graphic material in the courses under development, the partial automation permitted by the graphics digitizer would contribute to a smooth production process.

Terminals. The TICCIT terminal is really a color television set and an electronic keyboard. As modified for the TICCIT system the television sets display alphanumeric information along 17 lines with 43 character positions in a line. Characters themselves fall under computer control; programs can define as many as 512 distinct characters for use at one time. The dimensions for a graphic display would be 204 elements in the vertical direction by 430 horizontal elements. Both alphanumeric and graphic displays take advantage of the color capabilities of the TICCIT system to highlight key words, provide attractive material, and otherwise cue student attention. While such single frame displays use seven colors, the terminals can also receive full color videotapes with sound. These display capabilities together with access to audio messages give the TICCIT system a rich variety of instructional materials, especially in contrast to the teletypes and CRT consoles available at the start of the TICCIT project. Further, the use of a color television as a CAI terminal holds promise for other applications in the home based on coaxial cable communications.

The keyboard through which the student directs his instruction and responds to the TICCIT system resembles the key set on a standard typewriter (see Figure 1.2). That standard set of characters is sufficient for textual, numerical, and symbolic entries. A block of keys on the left side of the keyboard provides the student with some common controls for editing entries and positioning the cursor on the screen. More important to the design of the TICCIT program is the block of keys on the right side of the keyboard that defines a student's choices in TICCIT's teaching strategy. This learner control is an integral part of the entire system as it at once defines the extent of flexibility in teaching strategy and restricts the instructional design compatible with the TICCIT system. As installed at the demonstration sites the TICCIT program supports instruction under a learner control paradigm that is consistent across lessons, courses, subject fields, and schools.



Ax
Ax
MARK
NOTE
TAB
JUS-TIFY
ERASE
INSERT
ENTER
EDIT CONTROL
! 1
@ 2
# 3
$ 4
% 5
¢ 6
& 7
* 8
(9
) 0
– -
+ =
ALT CODE
{ Q
} W
ε E
√ R
θ T
° Y
∪ U
∩ I
ø O
π P
] [
RETURN
SHIFT LOCK
α A
Σ S
δ D
Δ F
R G
ℓ H
→ J
← K
| L
: ;
" '
SHIFT
< Z
≤ X
⊂ C
÷ V
β B
≠ N
· M
, ,
. .
? /
SHIFT
ATT'N
EXIT
RE-PEAT
GO
SKIP
BACK
OBJ'TIVE
MAP
AD-VICE
HELP
HARD
EASY
RULE
EX-AMPLE
PRAC-TICE
LEARNER CONTROL

TICCIT KEYBOARD

Figure 1.2

1.3.b Software

Software is what enables the equipment in a TICCIT computer system to fulfill specific tasks. For the main processor to shuffle student data from disc to computer memory and back, or the terminal processor to coordinate the delivery of textual, graphic, and audio messages to over 100 terminals, or the computer system to judge a student's response to a question as right or wrong requires software. Without such programs there would be no flashing lights, spinning tapes, or students learning on the TICCIT system.

The computer programs written for the TICCIT system fall into five functional categories. Operating systems and application programs relate to the delivery of instructional materials. Two other program packages, namely data entry and courseware processing, support the production and assembly of materials. A fifth function of the software is to provide utility services such as system protection against power fluctuations and disc management.

Operating Systems and Application Software. Together the operating systems and application programs allow mini-computers to deliver courseware and follow TICCIT's learner control paradigm for 128 terminals. There is an operating system for the main processor that brings courseware programs into core and executes them as appropriate for each student's instruction. A time limit on execution (79 milliseconds for a full load of 128 terminals) prevents one student's needs from interfering with instruction for other students, yet gives adequate time for system action. The main processor operating system (MPOS) also keeps an accurate data record for each student and feeds this to disc for use with the next cycle of courseware execution.

The terminal processor operating system (TPOS) serves as an interface between the main processor and the terminals. It actually sends messages to the terminals under MPOS direction and passes complete student entries on to the main processor for action. The routine input-output work, such as sending a student's key stroke back for display on his terminal or changing an entry as a student edits it, comes under the list of TPOS tasks as do a number of other housekeeping chores. This operating system, however, is far from routine in that it succeeds in reliable mini-computer service to 128 terminals.

The application software is a direct result of the approach to instructional design taken in the TICCIT program. All student entries rely on the application software for analysis and subsequent directions for a system response. Because these programs must be in constant use, each resides in core as an assembly language program in order to promote an efficient system response to student entries. It is with this collection of programs that data about a student's status begin. The application software sets the indicators and records the variables which reflect where a student currently stands in the courseware as well as the quality of his prior work. This information is essential for the system to determine an appropriate response to a learner control command or to make a recommendation about how the student should proceed.

Data Entry and Courseware Processing. An entire college course on the TICCIT system occupies a large number of display frames, just as a textbook with equivalent material would run to thousands of pages. There is software that partially automates the construction of these materials. For graphics a camera scans art work and computer programs record the result in source files. For text a member of the courseware production team prepares displays for rules, examples, and practice problems as well as the specifications for sequencing these frames and judging students' answers to problems. Such frame construction takes place at a terminal under author mode: software for data entry stores these frames in source files for text. Courseware processing involves the assembly of these source files and other data (e.g., tests and maps of courseware contents) into a form ready for delivery to students as instruction.

1.3.c Courseware

It is important to acknowledge the TICCIT program as a form of mainline instruction. The courseware for the program rests on the assumption that students would learn all the material required for college credit on the TICCIT system. This reverses the usual relationship between the teacher and the computer found in an adjunctive application of computer-assisted instruction. Rather than supplement classroom work, TICCIT takes primary responsibility for students' instruction while the teacher becomes an additional resource. So the courseware on the TICCIT system must be self-sufficient. It must contain all of the course material called for in a college's curriculum standards and deliver it in such a manner that students learn.

Obviously mainline instruction places a burden on the TICCIT program without precedent from other CAI systems. Yet the replacement of traditional classroom activities is a forceful argument for reduced costs through CAI. If the TICCIT program under an increased student-teacher ratio could release teachers from classroom lectures and free them for other tasks, the change in teacher productivity might justify the program's expense. The developers of the TICCIT courseware, initially the CAI Laboratory of the University of Texas and later the Institute for Computer Uses in Education at Brigham Young University, accepted this challenge and embarked on an approach to courseware production consistent with their concepts of market success and mainline instruction.

Content. After a study of potential markets for CAI, MITRE chose community colleges as the segment of education likely to be most receptive to the TICCIT program. Here there was a pronounced need for basic instruction coupled with a willingness to experiment with new methods that promised an improvement in student learning. Indeed enrollment growth at community colleges had begun to strain the limits of faculty teaching loads so the TICCIT program did not present a threat to jobs. Instead it offered a vehicle to meet local demands for instruction.

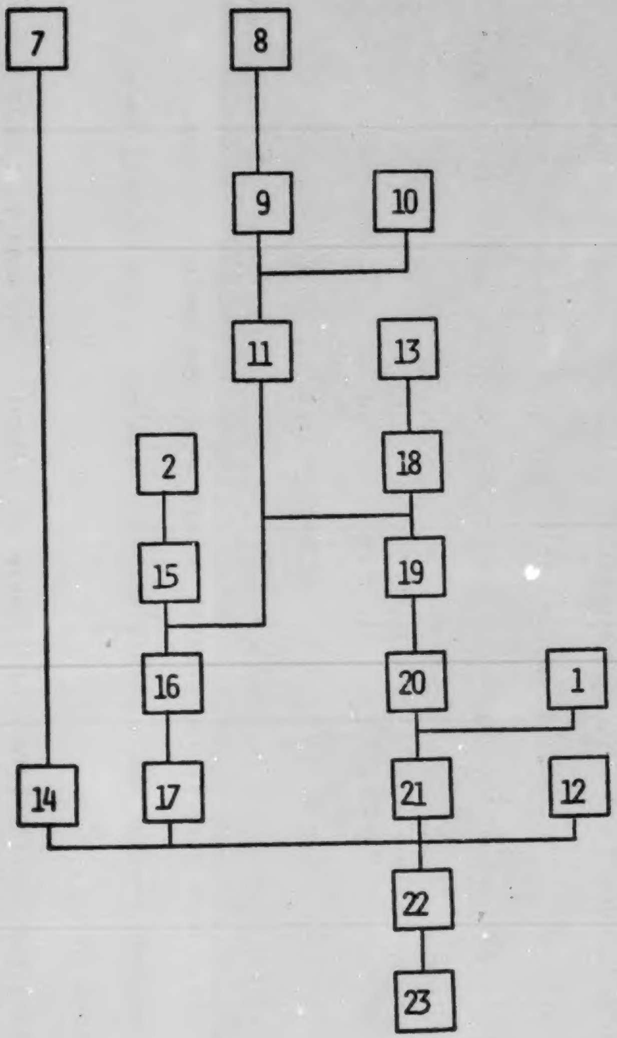
Within community colleges certain courses represent an inordinate share of the total curriculum in terms of enrollment. This is especially true for courses in algebra and writing skills where the numbers of students at a college require tens of sections each term. Further, if each student took just one algebra or writing course per term over a full two-year program, such courses would constitute twenty percent of the college curriculum by enrollment. MITRE therefore decided to implement the TICCIT program for precalculus mathematics and English composition. Outlines of the content coverage available in the mathematics and English courseware appear in Appendices A and B.

Basically the mathematics courseware contains the equivalents of introductory algebra, intermediate alegebra, and elementary functions. Beginning with a review of arithmetic skills, the algebra materials span common logarithms, linear equations, probability, arithmetic and geometric progressions, as well as other traditional topics like polynomial and algebraic expressions. The coverage for elementary functions includes polynomial, trigonometric, exponential and logarithmic functions with a brief treatment of conic sections in coordinate geometry.

The courseware for English compositon provides the equivalent of a writing laboratory with instruction in grammar, mechanics, diction, sentence structure and paragraph development. Unlike the TICCIT program for math, much of the students' work takes place independent of the TICCIT system as writing assignments. This reflects the general courseware objective for composition: clear and effective writing in a standard English style.

Structure. When a student begins a course on the TICCIT system, he or she encounters a series of maps. These maps chart the subject matter to be learned. Just as a textbook has chapters and sections, a TICCIT course has units and lessons presented on maps. Figure 1.3 is a unit level map for the precalculus courseware; Figure 1.4 is for the English composition courseware. These figures present all TICCIT courseware: a single math course might contain only four such units, as in the beginning algebra course at one demonstration site that requires units 23, 22, 20 and 17, or a student in a composition course might need work only in units 11, 10, 9 and 1 of the English courseware. Once a student chooses a unit within a course, there is a map of the lessons within that unit. The series of maps continues for three steps from units to lessons to segments. Each step yields further detail about the content coverage until a student reaches the segments within a lesson. At the segment level instruction occurs.

Unlike the outline format of a table of contents, the maps in TICCIT courseware adhere to a hierarchical structure. A segment below another on

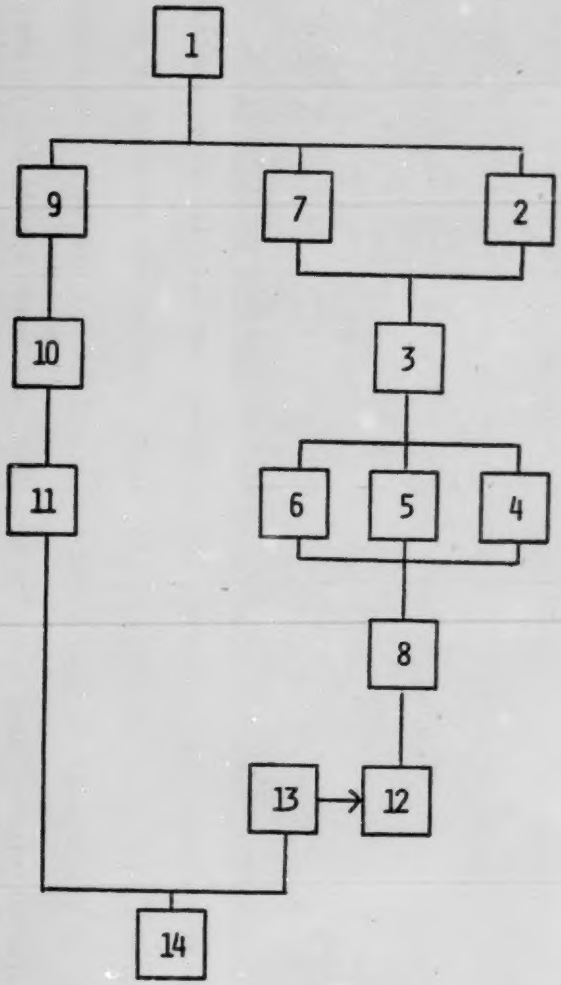


TICCIT MATHEMATICS

Unit Number	Topic
1.	PROBABILITY
2.	SEQUENCES AND PROGRESSIONS
7.	EXPONENTIAL AND LOGARITHMIC FUNCTIONS
8.	POLYNOMIAL FUNCTIONS
9.	FUNCTIONS
10.	CONIC SECTIONS
11.	RELATIONS
13.	MATRICES
15.	QUADRATIC EQUATIONS AND INEQUALITIES
16.	ALGEBRAIC EXPRESSIONS
18.	LINEAR SYSTEMS
19.	LINEAR INEQUALITIES
20.	LINEAR EQUATIONS
12.	SYMBOLIC LOGIC
14.	COMMON LOGARITHMS
17.	POLYNOMIAL EXPRESSIONS
21.	SETS
22.	RATIONAL EXPRESSIONS
23.	ARITHMETIC REVIEW
24.	INTRODUCTION TO TICCIT

TICCIT Mathematics Courseware

Figure 1.3



TICCIT ENGLISH

UNIT NUMBER	
1.	WRITING ESSAYS
2.	EFFECTIVE WRITING
3.	SENTENCE FAULTS
4.	PUNCTUATION AND CAPITALIZATION
5.	VERBS AND PRONOUNS
6.	SPELLING
7.	MULTILEVEL SENTENCES
8.	EXPANDING THE SENTENCE
9.	ORGANIZING ESSAYS
10.	WRITING PARAGRAPHS
11.	STRUCTURE OF WRITING
12.	ANALYZING SENTENCES
13.	BASIC ELEMENTS OF THE SENTENCE
14.	PRE-TEST
15.	INTRODUCTION TO TICCIT

TICCIT English Courseware

Figure 1.4

a map is a prerequisite to that higher segment. In general such a vertical connection implies that learning the material found lower in the path will facilitate learning in later, higher positions. For example, in the English courseware, the unit on writing paragraphs comes before that on organizing essays. Units adjacent to one another in a horizontal direction, on the other hand, share no definite relationship. Thus, the map structure for the subject matter depicts interrelationships among, first, units at the course level, then lessons, and finally segments. This structures student learning too as prerequisites determine content sequence and adjacent map positions provide a choice.

There is another dimension of structure which students do not encounter. It is that of the files on the TICCIT system. Files on discs hold the actual instructional materials. This approach allows the storage of extensive rule statements and instances to accompany each rule. The rule states the concept to be learned while the instances provide examples of its application and problems for student practice. Alternative versions of a single rule and its corresponding instances constitute a segment of instruction. All courseware on the TICCIT system eventually comes down to the level of segments, and, in turn, files of rules and instances.

Strategy. Much of the TICCIT strategy for teaching arises from its map structure. Boxes, whether for units, lessons or segments, colored green on a map display indicate that a student has mastered that material as demonstrated by performance on tests embedded at the lesson level or his solution of practice problems at the segment level. A red box signifies failure on a lesson test or repeated difficulty with practice problems, and hence a need for further work on this material. Yellow represents an intermediate state: there has been work on the material but not enough for a system decision about student mastery. When all the units in a course map turn green, the student has completed that course. The pretest for the English courseware assigns color codes to units based on a student's results for specific objectives, and thus expedites course progress. A student always has the option to take a lesson test first and, if he or she passes, avoid the study of familiar material.

Besides maps the TICCIT strategy for teaching relies heavily on learner control. A set of commands available at the segment level shifts responsibility from a system prescription for learning to a student's own initiative in his learning. Three commands correspond to statements of the rule that students must master (RULE), examples of its application (EXAMPLE), and problems for practice on its application (PRACTICE). The rule and instance files limit the total number of displays for these commands; but the student really exercises control over what order and how often he wishes to use RULE, EXAMPLE, and PRACTICE. It is also the student's prerogative to choose a difficulty level for examples and problems through the EASY and HARD commands. The same two commands, in conjunction with a RULE display, move a student to a more concrete or abstract form of what it is that he or she must learn.

When a student has trouble understanding a rule, following an example, or solving a problem, that student seeks further clarification through the HELP command. Then another rule display attempts to lead the student through a simple, step-by-step presentation. Or the student receives assistance on examples and problems as additional details isolate the attributes of the instance relevant to solution (for example, as different colors or format positions on his or her display) while textual or audio messages point to their importance. When the TICCIT system detects a student strength or weakness on tests and exercises, it volunteers advice about how the student should proceed. A student can request such recommendations for his or her learning strategy through the ADVICE command.

A learner in the TICCIT program has control, but not complete control, over instruction. Maps begin to define an appropriate sequence in terms of the subject matter. The set of available commands restricts the learner's choices at the segment level. The TICCIT program does not represent learner control in a natural language, tutorial setting. But it does provide learner control over a sophisticated drill and practice environment, and its instruction draws on recent advances in defining the conditions for learning.

1.4 Goals of the TICCIT Project

As with other innovations in education the TICCIT project began with ambitious goals. Unlike other major programs, however, the TICCIT developers set forth a clear statement of their position in early papers and held to the same goals throughout the project's history. This simplified the task of evaluation and, we believe, contributed to the evaluator's success in posing questions, collecting data, and interpreting results pertinent to the TICCIT program. Here we present the original goals of the TICCIT project from the perspective of its strongest advocates--its developers.

This project involves three distinct levels of goals. An obvious level within the field of instructional technology is the creation of a reliable, operational system with certain performance characteristics. Indeed a computer scientist might consider measures of system parameters like lag time to system response under different loads sufficient in themselves as an evaluation. Based on their simulation of system performance MITRE estimated that the TICCIT program would: support over 100 active terminals; respond to completed student entries within 1/2 second; echo key strokes within 1/4 second; execute 49,000 courseware instructions per student input. These estimates simplify to a system easily able to accommodate student instruction on an interactive basis.

Another level of goals relates to a market success. Community colleges, and later other sectors of education, would adopt CAI as an important new instructional resource. Private industry would provide capital investment for the production of hardware, software, and courseware, as well as invest in its dissemination through new marketing methods. Government and foundations would support major programs leading to the application of CAI to meet pronounced educational needs. Actually, the TICCIT project did not pretend that it alone would bring about such long-range goals. Rather it was to serve as a catalyst in the application of resources for developing and disseminating CAI for individualized instruction.

A final category of goals deals with the more immediate consequences of the TICCIT project. These were to occur as a result of the demonstration at community colleges. While an engineer might view consequences like student learning as remote in contrast to system performance, the learning that takes place on TICCIT constitutes the most important criterion among educators. It was the instructional psychologists responsible for courseware design who first elaborated the goals of the TICCIT program with regard to learning (see Bunderson, 1973). Their couseware design goals covered costs, student learning, teacher roles, and curriculum content. We repeat them here not as standards for evaluation but as initial ambitions of the TICCIT program.

Cost goals:

-- less than $1.00 per student contact hour
This figure reflects prorated system purchase and courseware costs, as well as maintenance and support personnel.

-- 25% less time to course completion
It would take students this much less time to complete a course as compared with the length of time required to complete equivalent work in traditional classes.

-- increase enrollment significantly
As a result of lower attrition rates, enrollment in advanced courses would increase while the popularity of TICCIT would attract more students to introductory courses.

Goals for students:

-- 85% of students will achieve mastery
Tests embedded in the courseware at the lesson level define mastery; the percentage refers to total course enrollment.

-- greater than a 50% improvement in the efficiency of student work
Between the start and conclusion of a TICCIT course, students would adapt to the system and become more proficient in their use of study time on the computer.

-- improvement in learning strategies
An improvement in strategy would accompany that in efficiency as evidenced by a decrease in students' reliance on TICCIT advice for guidance.

-- voluntary approach
Students' scores on attitude measures and their pursuit of optional course material would indicate a positive approach to the subject matter and favorable reactions to their learning experiences with the TICCIT program.

-- responsibility
With independent study and learner control, students would develop a sense of responsibility for their own instruction; this would be reflected in a high percentage of attendance at scheduled times for TICCIT classes.

Goals for educators:

-- define new professional roles in development as well as in counseling-management
While the TICCIT program would supplant the traditional role of a teacher

in the classroom, it would create new demands for contributions to further courseware production and for intensive work with students on an individual basis.

-- stimulate teachers to demonstrate humane values in follow-on or coordinate instruction

Content goal:

-- small step forward in content
The TICCIT program would not be a major curricular innovation: it would combine beginning and intermediate algebra into one modular system and attempt to implement a single course to replace the usual sequence of algebra, trigonometry, and analytic geometry; English courseware would adopt a generative approach to composition.

-- clarify objectives and provide flexibility
The specificity necessary in courseware production would force clarity on statements of content objectives while the modular design of courseware would provide flexibility in integrating the TICCIT program into existing curriculum structures.

Perhaps only an evaluator would devote serious attention to such goal statements. Goals, after all, tend always to exceed our grasp. But funding agencies consider program goals in allocating resources, schools in deciding about participation in experimental projects, evaluators in making judgments about data needs, and others in forming expectations. Since goals influence decisions, it seems reasonable that such statements balance an enthusiastic optimism about potential accomplishments and an historical realism about results of prior work. Here we took the developer's goals as earnest statements of intent which should guide, though not dictate, our attention in evaluating the TICCIT program.

1.5 Purposes of This Evaluation

What is a goal for a developer is often a question for an evaluator. This evaluation of educational impact covers the breadth of TICCIT's potential and goes into detail on key issues. The questions which the evaluation addresses, however, reflect not just the program's goals but also needs for information for making future decisions about the TICCIT program and similar projects. The community colleges involved in the demonstration must plan how best to use the TICCIT system once other participants complete their roles; other schools want sufficient data to decide about adopting CAI as an instructional resource. Certainly funding agencies must set priorities in allocating their resources and professionals in fields pertinent to instructional technology look for promise in new directions for research and development. This evaluation by itself does not satisfy all such needs. Rather it contributes to the information available to diverse audiences in making these decisions.

The evaluation concentrated on documenting outcomes and, to some extent, activities in four basic areas of inquiry. These were: student performance; faculty acceptance and teachers' roles; implementation; and instructional conditions. The major questions posed in the course of the evaluation follow.

Student Performance

- Student achievement: How does student achievement under the TICCIT program compare with that of students enrolled in regular class sections?
- Student attitudes: How do students react to TICCIT as an instructional program in contrast with traditional practices?
- Student activities: On what do students in TICCIT classes spend their time? How does this differ from normal class activities?
- Student conduct: How do institutional variables, such as enrollment and attrition, reflect student performance on the TICCIT system?
- Interrelationships in student performance: What characteristics distinguish among TICCIT students according to criteria of achievement, course completion, and total time spent on the TICCIT system?

Faculty Acceptance and Teacher Role

- Faculty opinions: What is the attitude of faculty members toward the TICCIT program?
- Instructor activities: What is the role of an instructor in the TICCIT program?

Implementation

- Project administration: What mechanisms, plans, and activities were involved in TICCIT implementation? How did courseware production take place?
- Site management: What does site management entail as exemplified at the community college demonstration sites? What changes took place in order to facilitate the introduction of the TICCIT program to the colleges?

Instructional Conditions

- Context for the demonstration: What is TICCIT? What constitutes the relative standard for the comparison of outcomes with those of the TICCIT program?

As should be obvious from these questions, there is substantial overlap in the purposes of this evaluation and the courseware design goals of the TICCIT program. The one significant point of departure concerns our repeated use of information from regular classes as a relative standard for comparisons, especially data on student performance, rather than rely on outcomes from TICCIT classes in isolation. Such standards were indispensable in gauging the effects of the TICCIT program: the results from regular classes became our benchmarks in determining whether an effect was positive or negative. Indeed the evaluator seldom accepts expectations, whether those of the developer or others, as standards for a project's success or failure. This evaluation points to relative strengths and weaknesses of the TICCIT program in contrast with the educational outcomes obtained through traditional practices.

The chapters in this report correspond to the questions raised in the evaluation. Separate chapters deal with course completion rates, achievement, attitudes, and activities as components of student performance. The analyses for characteristics that might distinguish among students in their performance appear within the chapter for the outcome in question. A chapter on faculty acceptance and teacher role comes after the treatment of student performance. Since TICCIT represents an innovative curricular program, an early chapter about implementation of the TICCIT program attempts to document highlights of its development and introduction into schools as well as experiences in its first year of operation at community colleges. A description of the conditions across comparison groups for the evaluation is given in this same chapter in order to set the context for the TICCIT demonstration.

That demonstration, and hence our evaluation, began after the TICCIT program had settled into the colleges' structure and when the developers felt confident enough to endorse the TICCIT program as a product rather than a mere prototype. Over a year of pilot trials at the colleges and even more time of system work at production sites preceded our evaluation of the TICCIT program. While one advantage of instructional technology is the relative ease of adaptation and refinement, the results from the demonstration period should apply to similar uses of the TICCIT program and forms of instruction close to TICCIT in design and manner of application. The nature of the TICCIT program and the consistency of our findings lead us to believe that this report presents an accurate picture of the TICCIT program's effects on instruction.

1.6 Matters Outside the Scope of This Evaluation

While this report touches on costs and system performance at certain points, the evaluation here focuses on educational issues. There is no comprehensive treatment of matters related to costs of the TICCIT program or the technical capabilities of the TICCIT computer system. Nor does this report record the history of the TICCIT project, either as charts of productivity or schedules of progress and slippage. Rather this evaluation constitutes a comparative field study of the educational impact of the TICCIT program.

It is also important to note limitations in the scope of this study. There is no definitive contrast provided here between TICCIT and alternative methods for teaching on an individual basis. Nor did the evaluation attempt to separate effects due to hardware, software, and courseware since the TICCIT program integrates all three components into one curriculum. Finally, cautions arise due to the context of the demonstration. It took place in courses for precalculus math and English composition at community colleges. Inferences about probable outcomes in other subject areas or at different levels of education would be premature.

Chapter 2

Methods and Measurement

An evaluation of a program as ambitious as the TICCIT project tends also to be complex in its range of activities. Much careful planning went into the design and conduct of the evaluation so that it would both probe critical issues in depth and cover the breadth of probable effects. Since we as evaluators were involved in the early phases of the TICCIT project, we had a unique opportunity to follow the program from its inception to its demonstration. And the evaluation benefited from this early exposure. Indeed the developers saw the evaluation as an integral component of the project and cooperated fully in its conduct. Hence we were able not only to lay careful plans but also to follow them.

This chapter is about the evaluation itself. The first section deals with the basic questions posed in the course of the evaluation as well as how we planned to address them. Subsections of the first section correspond to chapters in this report. The next section is the instruments constructed for the evaluation. Its organization reflects the major questions which the evaluation sought to answer. Given the issues and the instruments it is natural to move next to the procedures for data collection. The methods for data analysis appear as the fourth and final section of this chapter. The order of chapter sections simply follows the order of stages in evaluation and does not imply relative importance. For we view each of these stages as equally critical in that the strength of the evaluation depends on the separate strength of design, instrumentation, data collection, and data analysis.

2.1 Design for the Evaluation

The nature of the TICCIT program determined much of the design for the evaluation. This is as it should be for without a design sensitive to the treatment there would be little chance of capturing its impact. Yet it was also important to avoid bias toward TICCIT built into the evaluation. Often different curricular programs simply lead to different patterns of results (see Walker & Schaffarzick, 1974). Thus an evaluation which gave undue emphasis to one program's objectives might be expected to yield a significant difference in favor of that program. Our responsibility was to design an independent evaluation sensitive to TICCIT's potential while fair across instructional conditions and responsive to information needs.

The evaluation rests on a major assumption: that TICCIT represents a curricular program. In this case the computer is not merely an alternative delivery mechanism for the same instruction. Nor is the use of CAI a supplement to regular classroom work and therefore an addition to existing courses. Instead the TICCIT program makes full college courses available to students on an individual basis. The content coverage in such courses has to satisfy the guidelines of the established curriculum. Otherwise students would not receive credit for their work on the TICCIT system or fulfill the prerequisites for more advanced courses. Classes offered as part of the TICCIT demonstration were curricular alternatives to conventionally taught sections of the same courses. This evaluation treats sections taught by an instructor in a classroom format and those conducted on the TICCIT system with teacher support as alternative curricula.

While consistent in content coverage, TICCIT obviously differs in strategy and delivery. The learner-control courseware and the computer configuration with television receivers represent bold innovations in education. Yet neither is a self-sufficient curriculum: each is part of the TICCIT program. Therefore, the evaluation addresses TICCIT as a whole. No attempt was made to distinguish between courseware and hardware or to attribute effects to one component of the

TICCIT system or another. Such distinctions would run counter to the integrated design of the TICCIT program and require manipulation of school practices beyond the scope and intent of this evaluation.

It should be clear that this is a curriculum evaluation. The alternative curricula happen to differ along several major dimensions, including their strategy for teaching and mode of instruction. But the student learning that takes place within a course should satisfy the same minimal criteria. Comparisons of TICCIT with similar delivery mechanisms or contrasts across different instructional strategies for courseware would most certainly be helpful in selecting among such alternatives. Still, a consumer might view such studies as limited in their value if none of the alternatives matched or exceeded the results obtained through traditional, proven practices. Thus we concentrated on documenting TICCIT's effects relative to the outcomes of usual lecture-discussion classes.

2.1.a Focus of the Evaluation

It is common to judge the quality of an instructional program by its effects. This places emphasis on a demonstration of results rather than just an indication of potential. We expect such results will be evident among students as the group most affected by an instructional program. But teachers, too, bear the impact of curricular innovation through changes in their duties and responsibilities. These two groups, students and teachers, were the source of our data about the TICCIT demonstration.

From students we sought data on achievement, attrition, attitudes, and activities. Faculty at the participating colleges provided us with their reactions to and judgments of the TICCIT program, as well as reports on their professional role in TICCIT classes. These data reflect the basic questions about student performance and faculty acceptance addressed in the evaluation. What happens to students and faculty when the TICCIT computer-assisted instructional system becomes an operational part of community college instruction?

Student Achievement. Perhaps the single, most important criterion in judging a program's success is its effect on student achievement. Educators tend to look at achievement results before other outcomes, and most new curricula come with a promise to improve achievement in some manner. Certainly there was interest in whether the TICCIT program would result in higher test performance than that associated with usual classroom practices. Its developers hoped that TICCIT would lead to mastery of the subject matter for 85% of the students enrolled in mainline courses. Achievement, then, did receive the most attention in the evaluation.

Since the TICCIT program supports full college courses, it was natural to measure achievement at the start and end of a course. The pretests at the start of a course gave us a measure of students' entrance ability. The posttests indicated how much students had learned in their courses, and often instructors used them as final examinations. Our objective was to compare posttest performance, adjusted for entrance ability, between students in TICCIT classes and students in usual sections of the same course. If there was a significant difference in their overall learning within a course, and if we succeeded in eliminating or adjusting for extraneous factors, then that difference was a result of the TICCIT program.

The instructional design of the TICCIT program meant that it might affect aspects of student achievement other than those reflected on a posttest. TICCIT courseware has a highly modular structure. When a student completes a unit, he has mastered that material and need no longer refer to it. In contrast, an instructor might leave a topic and use later classes to review it or suggest its extension. If either a student forgot material from TICCIT or a student picked up concepts from repetition in lectures, then posttest results tell an incomplete story. Measures taken at the time a student completes initial coverage of a topic might reveal differences which do not show on final examinations. Where course structure permitted, we used topical tests as measures of immediate learning to supplement the information available from posttests.

There were other features of TICCIT's design that had the potential to affect achievement in another way. A student on the TICCIT system could proceed at a rate suited to his speed in learning. Also he could take advantage of a machine's patience for repetition and drill. TICCIT's learner control further expands the range of choices available to a student. With such an opportunity a student might master and overlearn material. Indeed, a study of programmed learning suggests that learner control can facilitate retention even if no effect on acquisition is apparent (Newkirk, 1973). We made special efforts to track students across academic terms so that tests administered in subsequent courses might serve as measures of retention.

Thus, the evaluation covers three critical components of student achievement: (1) overall learning as measured by final course examinations; (2) immediate learning as assessed in topical tests; and (3) retention as reflected by tests given in later courses. Math courses lend themselves to such a testing scheme: each course includes several topics, like units in TICCIT courseware or chapters in a textbook, and often two or more courses make a sequence spanning introductory algebra to calculus. Courses in English composition do include posttests, but they lack the discrete topics common across classes that would be necessary for topical testing. Further, a sequence of English courses follows from student interests in different literary forms, such as the short story or poem, rather than from logical content interrelationships. So the evaluation had to concentrate on samples of the criterion task in composition courses. We took writing samples, as well as administered multiple-choice tests of writing skills, at the start and end of English courses.

Course Completion Rates. We usually think of course completion rates in a negative sense as attrition: what proportion of the students dropped out or otherwise failed to complete their studies? In this report we prefer to use attrition's positive complement, simply the proportion of students who do receive course credit. This estimate is more consistent with a view of education as a productive system. Indeed, if we consider achievement to be a measure of a program's quality, completion rates indicate a program's success in terms of quantity. Perhaps a math department would sacrifice a few points on a final examination for a curricular program that increased its course completion rates. Productivity in higher education is really a combination of student achievement and course completion rates.

Unlike students at lower levels of education, college students can give concrete expression to their dissatisfaction with instructional conditions or disillusionment with their own performance by formally withdrawing from a course or simply failing to appear for classes. This is an obvious form of attrition. Completion rates are subject to subtler influences, especially with instructional programs geared for the individual student. A student may continue to attend classes regularly but still not complete the amount of material required for course credit. That student would receive a grade of incomplete or another grade which indicated that he had yet to finish the course. We can adjust our estimate of completion rate so that it is sensitive to such incidents.

This report presents three different estimates of the completion rate for TICCIT and lecture classes. The three correspond to: (1) the proportion of students enrolled for the course who receive course credit; (2) the same proportion corrected for early course withdrawals; and (3) the proportion of students who make satisfactory course progress to the total course enrollment. Each of these figures (examples and further explanations can be found in Chapter 4: Course Completion Rates) reveals something different about the TICCIT program. We begin to see how an innovative curriculum project affects an institution's productivity. Marked contrasts between an individualized program and a group teaching method also emerge. The direction of these contrasts depends on how we choose to define completion.

All of our definitions for completion rely on grades given at the end of an academic term. If the amount of time a student needs to master an entire course does depend on his entrance ability (see Bloom, 1974; Carroll, 1963), then an academic term represents an arbitrary unit of time. More able students will finish sooner while students less proficient in terms of their initial skills may take longer. So it was important that the evaluation track not only course completion within an academic term but also enrollment in subsequent courses across terms. Enrollment trends across terms might reveal effects hidden by completion rates taken within an academic term. From enrollment figures matched with the instructional condition from previous courses we can check on whether an introductory algebra course on TICCIT leads students to continue with intermediate algebra. Such a positive effect on students' progression through a course sequence should take place. Otherwise teachers displaced from introductory courses would find no teaching demand as a counterbalance (unless the TICCIT program instead attracted additional students to the introductory courses).

Just as completion and enrollment interact with college productivity and teacher role, so a variety of factors really come together in these student counts. Completion rates reflect students' academic progress, their own satisfaction with that progress, extracurricular commitments like family or employment, as well as possible variations due to subject matter, level of course, or teacher. Where possible we collected information on these variables so that we could isolate the effects of the TICCIT program. But it is helpful to think of completion rates and enrollment trends as measures of student performance that become evident at the level of the institution. While college administrators might not see TICCIT results in terms of posttest scores or attitudinal responses, they will receive enrollment summaries and grade distributions. We simply made that level of TICCIT's impact a routine part of the evaluation.

At the time of our initial plans (Alderman & Mahler, 1973), we did not know the importance that completion rates would assume. For should a curricular program lead to a student population completing their studies that is in some way different from the reference group under another program, all measures taken at the end of a course incorporate this bias. Statistical analyses can compensate for systematic bias but only in a partial and imperfect sense. Completion rate would then represent the only true indicator of program results.

Student Attitudes. Over the last several years it has become common for students to rate their teachers (e.g., Brown, 1976; Costin, Greenough, & Menges, 1971). This practice gives implicit recognition to the role of students as judges. It also extends the criteria for teaching effectiveness beyond achievement and productivity to results in the form of student opinion. Indeed, studies of computer-assisted instruction use student attitudes to explore the advantages of CAI (e.g., Mathis, Smith, & Hansen, 1970; Summerlin, 1971). Despite the acceptance of student ratings and the study of student attitudes toward various teaching methods, curriculum evaluations seldom compare programs along this dimension. Yet comparisons of student attitudes, especially with dissimilar programs, offer us insight into how students react to teaching methods and what they value in their instruction.

As with achievements results, an evaluation of student attitudes requires a relative standard. Where there were other sections of the same courses, we had access to such a standard for gauging the affective outcomes in TICCIT classes. Again, then, our estimate of a strength or weakness in the TICCIT program depended on what results already occurred. But instruction in lecture-discussion sections involves teachers and textbooks; instruction in TICCIT classes involves television receivers and keyboards. Obviously we had to seek their common denominator if we wanted to make comparisons across conditions. Neither rating teachers nor assessing student acceptance of CAI would contribute to our evaluation of the TICCIT program as a curricular alternative.

Our attitude survey, instead, posed questions about students' satisfaction with their class and about the usefulness of important features in their instruction. For the most part these questions dealt with aspects of a course common to both TICCIT and lecture sections. So students responded to identical statements. Where a specific TICCIT feature had a strong parallel in regular classes, we drew a correspondence between them and considered the statements identical for purposes of analysis. Two items from the survey illustrate this point: all students indicated their extent of agreement with "Instruction in this class met my own particular needs"; students in TICCIT classes also responded to "TICCIT's comments on my work (ADVICE) helped me to progress through this course" while those in lecture sections reacted to "The instructor's comments on my work helped me to progress through this course." The latter pair of statements reflects the stand-alone, mainline design of the TICCIT program; teachers would provide help with planning and selecting strategies for student learning, but the system itself would be the primary resource for advising students on their course progress and guiding them through the curriculum.

Experience in pilot trials for the evaluation had taught us two important points about student attitudes. The first was that students viewed the TICCIT program as distinct from computer-assisted instruction. It was much easier for them to respond to statements about TICCIT in particular than to make judgments about CAI as a generic whole. Thus the statements in our survey refer to TICCIT, and we draw no broad conclusions about student attitudes toward CAI in this report. The second point was closely related: students had difficulty reacting to statements about CAI when they had no prior exposure to computers. Confronted with a questionnaire about their predispositions toward CAI, students tended to repeat what they had heard in their orientation to the TICCIT system. There was no apparent mechanism in evaluating attitudinal impact that would be comparable to an achievement pretest. Our approach to this issue relies heavily on straightforward contrasts between responses from TICCIT sections and those from regular sections of the same course.

Student Activities. Results in terms of student achievement, course completion rates, and student attitudes describe what happens to students. But what do students actually do on the TICCIT system? How would students use the learner control options? Would the amount of time required to attain mastery be a function of students' entrance skills in the subject matter? These questions suggest the uncertainty involved with the first field trials for the TICCIT program. The concepts behind the program were innovative and experimental, and hence how, or indeed if, students would exercise learner control with mainline instruction was an open question.

Unlike our comparative approach to evaluating other components of student performance, our emphasis for documenting student activities fell primarily within the TICCIT condition of a course. At first, field representatives working for the evaluator made direct observations of the interaction between a student and the TICCIT system. These laborious observations were replaced by automated data collection on the TICCIT system when the necessary programs became available. None of lectures, class discussions, or even programmed textbooks had a counterpart to the individual student sessions that take place at a TICCIT terminal. So our study of these interactions necessarily focused on issues within TICCIT classes. We chose to address (1) students' use of learner control, (2) sequences and dimensions which describe that usage, and (3) the relationship of mastery to study time and entrance skills. From such a focus we should be able to determine whether the TICCIT system promotes and accommodates different learning strategies.

Still, there were questions about student activities that require a relative standard. If the TICCIT program had an effect on the frequency of students' interpersonal contacts or the efficiency of students' course work, these effects would be evident only in contrast to the contacts and study requirements of other course sections. We relied on student self-reports to give us estimates of both the extent of personal interaction and the time spent on a course. Thus, students estimated the frequency of their course-related contacts with other students as well as with the instructor for their class, and the number of hours per week devoted to class attendance and homework as the two primary time demands of a course.

Admittedly, a self-report is not the most accurate way to track student activities. It does, however, allow an evaluator to obtain an indication of a significant difference. For should there be a substantial change in his routine study habits, a student should notice it. If the difference were so subtle as to require that the evaluator monitor students' activities, perhaps then its detection consumes more in evaluation resources than it justifies. We should still remember that the study burden imposed by an instructional method is a real cost, if not for us then for the students who must spend the time.

Faculty Acceptance and Teacher Role. There was as much uncertainty about what instructors would do in TICCIT classes as about student activities. If the TICCIT program succeeded in teaching students and enabled them to adjust their own instruction to fit individual needs, what then would be the teacher's role? The developers of the program foresaw a displacement of teachers from introductory math and composition courses. Instructors would assume new roles as master teachers in advanced courses, as subject matter experts on teams engaged in courseware production, and as researchers concerned with concrete instructional problems (see Bunderson, 1975). But such role changes were beyond the scope of the TICCIT project and demonstration.

Within the period of the demonstration the developers hoped to prepare faculty for a shift in their teaching responsibilities and classroom duties. The TICCIT system was to fulfill the usual teaching role: it would convey and explain material as well as facilitate student learning through its advice. The teacher in a TICCIT class would function as a manager-adviser, helping students to make choices and plans for their learning on the computer system. So the teacher would become another resource available to students rather than the central figure in instruction.

Such changes in the teacher's role might appear overly ambitious, either from the perspective of a doubtful faculty member or from the viewpoint of someone convinced of the conservative nature of education. As a program goal, however, it indicated a need for attention to teachers' activities in the evaluation. The simplest method for gathering data on teacher duties was to distribute a questionnaire to all instructors responsible for sections of target courses. That questionnaire required teachers to estimate the class time spent in different teaching modes (e.g., lecture, discussion, programmed textbook, TICCIT system, tests and quizzes) each week, and their own allocation of time as a percentage distribution among various teaching duties (e.g., planning for class, preparing lectures, conducting class). Each section assignment called for separate estimates, with general faculty duties unrelated to specific sections covered on another part of the questionnaire.

Two other sources lent descriptive support to the teachers' activity reports. Records of students' requests for assistance, kept as part of our observations of student interactions with the TICCIT system, and class observations undertaken for both lecture and TICCIT sections, helped us to appreciate what instructors' responses meant.

Proponents of CAI cite school resistance as one reason for the slow spread of instructional technology. This must be at least partially due to faculty acceptance. To assess faculty positions on the assumptions behind TICCIT and to track their reactions to the program, the evaluation included a series of three, annual attitude surveys. These faculty surveys also gave us access to expert judgments in the form of educators' opinions, the opinions of those teachers closest to the project.

2.1.b Comparison Groups

It should be obvious, after so much repetition of the point throughout the discussion of student performance, that the evaluation of the TICCIT program depended on comparison groups. For each target course in the demonstration there had to be both classes offered on the TICCIT system and sections taught in traditional classrooms. In one case there were also sections that used programmed instruction. Such alternative programs of instruction were essential if we were to evaluate the outcomes of the TICCIT program in relation to already attainable results. Without a relative standard there would be no way to know the difference between a strength and a weakness in the program, and thus no basis for future decisions about TICCIT.

Actually, it is not quite accurate to describe the TICCIT program as an alternative to existing courses. This implies that it leads to similar, if not in some way preferable, results. As evaluators we believe such a description premature in the absence of data. What the TICCIT program really represented at the start of the demonstration was a competing curriculum. Especially with an independent evaluation contracted for the demonstration, TICCIT had to compete with whatever practices were already in place at the colleges. And it had to produce at least equivalent results, or else an acceptable balance of results, should comparisons across outcomes prove uneven. Otherwise it would be difficult to make a case for school adoption of a TICCIT system.

Our treatment of completion rates, student achievement, and student attitudes rests on comparisons made across teaching methods. The importance of these comparisons, both to the credibility and generalizability of the evaluation and to the participants in the project, justified careful attention. We did exercise care in selecting the criteria for comparisons, checking the equivalence of student groups at the start of an academic term, and looking at the actual instructional conditions.

Criteria for Comparisons. Wherever possible the criteria for comparisons were identical across course sections. For completion rates this meant that we considered a letter grade in one section to mean the same thing in another section. True, one teacher might mark on a different scale or distribution than his colleagues. But our primary interest was whether a student earned a grade sufficient to receive course credit, not how high a grade a student received. There were departmental policies that affected grades like incompletes and withdrawals, so the danger of bias due to individual teachers was minimal. Still, a collective faculty prejudice might cause completion rates to differ across conditions. As evaluators familiar with the colleges we did not believe this would happen. We also knew that such prejudice in assigning course grades, if it existed, would show in our analysis of achievement results as an effect in the opposite direction.

The need for a common, shared criterion is perhaps most pronounced when evaluating results in terms of student achievement. Should objectives or content coverage differ among competing programs, this discrepancy rather than a real difference in effectiveness might lie behind the significance of statistical tests. It is therefore useful to restrict the basis for comparisons to only those objectives held in common across programs (e.g., Popham, 1969). Shoemaker (1972) points out that as the number of programs increases and as it becomes necessary to infer objectives, the size of the common basis must shrink.

With just two or three alternative methods for instruction and a well-defined content domain, there was substantial overlap in objectives for math courses. Indeed all sections, regardless of method, had to meet the same curriculum standards. So, with the cooperation of both the math faculty at the colleges and the developers of the TICCIT math courseware, we classified each posttest item as one that reflected either a common objective, an objective unique to one program, or an objective beyond the course's scope. Our comparisons of achievement results in math courses use the posttest score for just those items reflecting common objectives.

The statement of objectives for TICCIT courseware was as explicit in English composition as in pre-calculus mathematics. But there was a variety of approaches among instructors on how writing is best taught to students. Thus there was disagreement on, for example, whether a student had to know about proper use of the semicolon in order to write well. This lack of a consensus within the English departments also meant that it would be quite difficult to specify a set of objectives common to TICCIT classes and lecture-discussion sections. Still, despite differences on how composition should be taught, the importance attached to a student's actual writing was not subject to dispute. Instructors, among themselves or with the developers of the TICCIT courseware, might disagree on certain basic skills as appropriate course objectives. But the overriding objective in the composition courses was clear and effective written communication. We took writing samples from students as the best indicator of course-related achievement.

Unlike the explicit statements of objectives (or implicit in content coverage) associated with student achievement, curriculum impact on student attitudes was left unspecified. Of course both the TICCIT developers and college faculty hoped that students would react favorably to their courses. In addition, there were a number of general advantages claimed for the instruction available with the TICCIT program. For example, mainline instruction combined with learner control was to make students more responsible and more actively involved in their own learning. It would also permit a student to set a pace right for his own particular abilities and to receive individual attention from an instructor. But would the TICCIT program really improve the extent of a student's active participation in his learning, and to what extent did lecture-discussion classes already meet the advantages traditionally advocated for CAI? It was appropriate for the evaluator to apply the same criteria across sections and instructional conditions.

Whether in TICCIT classes, lecture sections, or programmed instruction classes, students responded to essentially the same attitude survey. The survey had statements drawn from popular claims about CAI as well as specific features of the TICCIT program. It dealt generally with students' satisfaction with their course. For each statement a student responded on a scale from strongly agree (coded 5) to strongly disagree (coded 1). We compared results from TICCIT and lecture classes in terms of the student's attitude score for about 20 items. These were the statements which were identical or closely parallel across instructional conditions.

Formation of Groups. Assessing outcomes in terms of the same criteria is one step in program evaluation: assuring the equivalence of groups exposed to different programs is another. The preferred method to assure equivalence is to assign students to groups on a random basis. Then there would be no grounds for belief that preexisting differences, like entrance ability in the subject matter or demographic variables such as sex or age, affected outcomes in one group in a somehow different manner than outcomes in another group. As an extreme case, consider what might happen if all students motivated to complete their studies enrolled in familiar lecture sections: we might then expect results for course completion rates to favor lecture instruction although another variable was actually responsible for the difference between comparison groups.

Of course completely random assignment was inappropriate for the TICCIT demonstration. Such a procedure would in effect cancel the student's prerogative to choose courses. At best those students seeking to enroll in a target course could be randomly assigned to a condition. This was the procedure followed at Phoenix College, with the consent and cooperation of math faculty members, for the fall semester of 1975-76. But more often the constraints imposed by registration, class time schedules, space availability, and faculty or staff hours, make random assignment unfeasible. The evaluator cannot enforce experimental control which disrupts college operations as well as services to students. Even when we succeeded in arranging for a truly random procedure, students with strong objections were allowed to change their assignment to an instructional condition.

An evaluator responsible for a comparative study of curricula usually has to seek an alternative to random assignment. And we did implement an approximation to random assignment at the Alexandria Campus of Northern Virginia Community College. The fall and winter (1975-76) schedules for classes at Alexandria did not identify which sections of a course were TICCIT classes. Instead the schedule listed just the time, room, and instructor, along with the course title and number. Where programmed instruction was already available for a course, the schedules maintained the precedent of earlier years and identified sections as "lecture" or "programmed." In this case, the TICCIT classes were actually a subset of those "programmed" sections. It should perhaps be noted that such a procedure is an attempt to guard against the formation of nonequivalent groups rather than an explicit method to create equivalent groups.

We had taken care to arrange for random or quasi-random enrollment in comparison groups so as to eliminate sources that might contaminate evaluative results. Campbell and Stanley (1963) note the strength of the pretest-posttest control group design, as ours would be for achievement, and the posttest-only control group design, as ours would be for completion rate and student attitudes. Such experimental designs presuppose random assignment without alterations to groups during the period of the study. But students would withdraw from courses or otherwise fail to complete a course. Then not all students would take the achievement posttests or attitude surveys, and the evaluation design for these outcomes would degenerate into what Campbell and Stanley (1963) call a nonequivalent control group design.

Indeed, we found pronounced differences between the number of students who started a course and the number who finished it with credit. This fact, together with preregistration by mail for the second term and student wishes to reenroll in a math course under the same condition as in the fall, convinced us that we had to abandon random assignment for the spring semester at Phoenix. While the English composition course at Alexandria continued to mask the identity of classes which included TICCIT use, math courses there had sections listed with the appropriate instructional condition by the spring quarter. Again the change from quasi-random procedures to selection at the student's discretion.

It might be argued that such student selection conforms to what other colleges do and hence is more representative than a forced and artificial random procedure. Or that college registration itself is a quasi-random procedure. However, we knew a nonequivalent control design would not be as strong as a true experimental design. It does not permit the same inferences to be made unless we eliminate competing explanations for group differences. These sources of invalidity in our analyses for achievement and attitudes should show first under completion rates.

If there were a differential effect on course completion, involving an interaction between class condition (i.e., TICCIT, programmed, lecture) and some student characteristic, then the students who had taken the posttest and attitude survey at the end of the course already constituted one dimension of educational impact. One method of teaching had eliminated certain students from the population taking posttests and surveys in a manner dissimilar from that of another teaching method. Of course a method might also permit certain students to complete a course while another would not. The point is the same: the differential effect would be built into the analyses for achievement and attitude results. And further interpretations of achievement or attitude results would have to be cautious and conservative. In the absence of differential (not just different) effects on completion, we could continue our analyses of TICCIT's impact on student performance.

With nonequivalent comparison groups it became important to document what the groups were like and to gather additional data from students. Information about students' reasons for selecting a particular section along with a rough student profile (e.g., age, sex, grade point average) would permit closer study of the comparison groups than pretest score alone. We collected this background information as soon after registration as possible, usually on the first class meeting or within the first week of classes. It gave us data on why students chose particular sections of a course so that we could understand the process behind group formation. It also provided data through which we could check for differential effects both as a threat to inferences from achievement and attitude results, when such effects arose in completion rates, and as evidence that one method of instruction might be better for a specific subgroup of students, while another method had greater success with the rest of the student population.

Context for Comparison Groups. An assumption perhaps buried in the complexity of an evaluation is that the alternative curricula represent well defined conditions. We too made this assumption in developing our strategy for data analysis. At first this may seem an unwarranted leap considering the flexibility of the computer and the variety of teachers' styles. But recall that our criteria for comparisons depend on objectives common across groups, especially with regard to student learning. So there were specific objectives that defined what was to be taught in a class and thus learned by students. The college curriculum standards further specified content coverage within a course, and our comparison groups formed within each course.

Still there might be substantial variation, if not in what was taught, then in how it was taught. Yet there was an obvious difference between comparison groups in this respect. Those classes considered part of the TICCIT condition received instruction through the TICCIT system. Sections included under the lecture condition were taught by an instructor and assigned a textbook. The one course that also had a programmed condition actually was offered with programmed texts. At least in terms of the primary resources for teaching, conditions were well defined.

As we might expect from the dissimiliarities in the subject matters, there were differences between the math and English courses in the approach taken to teaching. Math courses tended to be highly structured and sequential. English courses, on the other hand, were much more dependent on the instructor's professional judgment of the manner best suited to teaching composition skills. This is not meant to imply a stereotype method for teaching pre-calculus mathematics, for there were differences in strategy if not in overall content structure and sequence. Subject matter dissimilarities would naturally preclude comparisons across courses but should not interfere with comparisons across conditions for the same course.

These general statements about comparison groups appear now, perhaps at too early a stage in our discussion, so that we can begin to define the context of the TICCIT demonstration and the limits of our attention to the instructional process within each class section. We sought only to confirm basic expectations about what happens in lecture and programmed sections. Through occasional observations and contacts with instructors, we came to know that a class did indeed belong under the lecture or programmed condition. This minimal investment of resources helped isolate exceptional cases that might later surface in analyses, such as the lecture section found in pilot trials in which the instructor permitted each student to set his own pace and complete the course prior to the end of the academic term, or the section scheduled to use TICCIT in the demonstration period which did not. To find these exceptions and get a better description of conditions were our modest purposes in classroom observation. We did not attempt to tie particular teaching practices with section by section results.

There was not sufficient precedent for us to form definite expectations of what the TICCIT program would be like. Here we did want to document what happened in a class and again describe the instructional condition as a whole. But with the use of the TICCIT system often at the discretion of the instructor, particularly when the TICCIT program served as the laboratory component of a composition course, it was necessary to supplement our direct observations. Records of students' progress in the TICCIT program were available on the computer system. These records indicated what material a student had studied and mastered, as well as how much time the student had spent on the system.

Online data summaries for TICCIT classes and observations conducted on a regular basis were our primary sources for descriptive information on the nature of the TICCIT program as a comparison group.

Clearly classroom observations played a limited role in our evaluation. Judging teacher competence, keeping detailed section histories, and drawing inferences about the instruction within a single class all go beyond the scope of this evaluation. Our observations were made simply to confirm what happened in types of classes and to describe the context for our comparison groups in broad terms. The college standards met by the TICCIT program in order to be offered as part of the regular curriculum and our emphasis on common criteria for outcome measures already defined courses, regardless of condition, to a great extent. And the TICCIT program was itself well defined from the standpoint of curriculum objectives, content coverage, and teaching strategy.

2.2 Instrument Preparation and Properties

Ask an evaluator a question and an instrument for data collection is apt to precede his answer. At least three major options were open to us in selecting instruments. We might choose to measure TICCIT's impact through standardized tests and surveys. Due to their demonstrated characteristics and widespread use, standardized instruments offer a convenient solution for obtaining measures of results. But such a test is often insensitive to the particular program under study in that its match with the curricular coverage omits much detail (Shoemaker, 1972) and its aim is to assess a student's knowledge rather than a program's results. Similarly, surveys of attitudes and activities broad enough to be available on a commercial basis often omit the very questions most germane to the particular program. We also found a dearth of standardized instruments specifically developed for community colleges, an unusual fact given their growth rate over the last two decades.

Criterion-referenced instruments offer another means to assess a program's impact. Indeed such tests would be consistent with several of TICCIT's goals, most notably that 85 percent of students attain mastery. And criterion-referenced tests correspond to the curriculum under study. However, this mode of testing implies a firm grasp of what constitutes mastery, a concept that still is subject to numerous interpretations (Stake, 1970), and bypasses measuring the extent to which material is learned (Ebel, 1973). Goals of the TICCIT program besides student achievement, like those for improved completion rates and better student attitudes toward learning, required a relative standard rather than an absolute criterion.

A third tool with which we can capture the impact on student performance and faculty acceptance is special tests developed for the specific program's evaluation. This is the option we pursued. It enabled us to focus our achievement test on the material taught in target courses and to develop questionnaires and surveys that met the specific needs of the evaluation. Special tests also permitted us to engage in constructive exchanges with the developers of the TICCIT courseware and faculty members at participating colleges, and to make revisions to our instruments as warranted by faculty comment or data from pilot trials. However, there is a burden associated with these benefits. Besides devoting resources to instrument preparation, an evaluator must demonstrate the properties of specially constructed measures.

2.2.a Student Performance

The process of preparing instruments particularly suited for the TICCIT demonstration was especially critical to our assessment of student performance.

Not only did we need fair measures of achievement, attitudes and activities, but we also had to develop items, conduct pilot trials and revise the instruments prior to their use during the demonstration period. At times it seemed the process might never come to a close. There were changes in the colleges' plans for integrating the TICCIT program into their own curriculum structure and uncertainties about the courseware due to delays in its production. On the other hand these departures from the project's schedule gave us time to hold field trials for the instruments and refine them. When the demonstration began, the achievement tests, student attitude surveys, and activity questionnaires were ready.

What follows is an historical account of how we developed these instruments and a presentation of data pertinent to their reliability and validity. This section does not convey any results of the demonstration. It reports only that data necessary to demonstrate instrument properties. We might be tempted to skip much of the detail here but for a belief that the accuracy of our results rests, in part, with the instruments.

There is an obvious omission from this account: completion rates. The college grade sheets contained the data about course completion. At each college we contacted instructors to verify what different grades, like those for withdrawals and incompletes, meant. There were also different college policies from term to term and different standards for grading from instructor to instructor. But we generally accepted whatever grades appeared on the class rosters as the most meaningful definition of course completion. These grades, after all, determined whether students received academic credits.

Achievement Tests: Math. Even before colleges agreed to participate in the demonstration of the TICCIT program, the process of test construction had begun. Specialists in developing math tests first reviewed an outline of content coverage and statement of objectives in 1972. It was clear then that the TICCIT program would approximate a pre-calculus course and a beginning algebra course. The pre-calculus course followed the recommendations of the Committee on the Undergraduate Program in Mathematics (1969) for a Math 0 course that met the requirements for transfer to four-year colleges. The beginning algebra course was very much like those already offered at community colleges to meet the deficiencies in student preparation so common under open enrollment. It was a sound, traditional curriculum plan.

There were two prominent reasons behind our early decision to prepare special tests for the math component of the TICCIT program. Obviously a revolutionary outline of content coverage was not one of them. Instead it was the scarcity of commercial tests appropriate for community colleges and the insensitivity of standardized tests to specific courses. With a commitment made to engage in test construction, it was possible to anticipate the demands of this activity in terms of the evaluation's schedule and resources.

In general the schedule of the evaluation had to follow that of the TICCIT project itself. The first full academic year of the evaluation, 1972-73, passed without data collection but with much progress toward satisfactory achievement tests in math. Examiners (as we prefer to call test specialists) reviewed the specifications for the math courseware. When two colleges were selected to serve as demonstration sites, the same examiners visited the math departments and obtained the syllabi and textbooks used for algebra and pre-calculus courses. This information was sufficient to develop a pool of test items. While the developers continued their work on courseware throughout 1973-74, our examiners went over the item pool with both the math faculty from the participating colleges and the math authors from the courseware production team. The resulting posttests were given field trials before the close of the 1973-74 academic year. Thus the posttests for algebra courses were available during the implementation period for the TICCIT project. For it was not until 1974-75 that TICCIT systems were installed at the colleges and pilot versions of the algebra courseware tried with community college students.

The pre-calculus coureseware was about a year behind the production schedule for the algebra curricula. Uncertainty about the availability of TICCIT pre-calculus units and an abbreviated trial period for this courseware (one academic term) prevented us from following as thorough a test development process as that for algebra courses. But we had learned from the earlier item review procedures and pilot testing, and so we were able to develop and validate tests for pre-calculus courses within the fall academic term of 1975. Again, posttests were ready in advance of the demonstration. It was the start of the 1976 calendar year when the colleges offered multiple sections of pre-calculus courses on the TICCIT system.

Besides the posttests for algebra and pre-calculus courses, our evaluation called for measures of student achievement that would tap immediate learning and retention. But posttest preparation took precedence over these measures. Developing tests on particular topics, which were to be measures of immediate learning, began after our initial versions of the posttests had been tried at the colleges. Still it was possible to develop and pilot topical tests early in the academic year after posttest field trials: it was the fall term of 1974 when the colleges first administered the topical tests on linear equations and algebraic expressions. The construction of these tests was, by then, a straightforward procedure. We had an extensive pool of test items that covered both topics, and had already been through test reviews by faculty and authors. The same item pool and experience eased the preparation of tests for retention. These were to be administered as course-specific pretests in the academic term subsequent to student completion of a target course. They were also the last math achievement tests in terms of our priorities for preparation and the schedule for test construction. Thus it was the demonstration period of the TICCIT project, 1975-76, before we reached this stage in test preparation.

Perhaps it seems that the preceding account has omitted an essential component of the achievement testing in math courses. It has not touched on pretests as controls for students' entrance skills. This is because the general pretest differed from the other measures of achievement in an important respect: it was a standardized test. We had considered the use of special pretests but rejected them. Although the same pretest as posttest might enable us to compare curricula in terms of achievement gains, there would be dangers to such a testing scheme. It might simply alert students to what final exams would cover and thus pose a test-reactive threat to our study's validity (see Campbell & Stanley, 1963). It might also be inappropriate to make curricular comparisons on the basis of change scores from pretest to posttest (see, for example, Cronbach & Furby, 1970). On a more basic level it made little sense to ask students questions about material they had not been taught. Then we would expect consistent, low scores. What we sought instead was a general test of students' background and preparation for math courses. Such a pretest would reflect differences in students' entrance ability and, presumably, account for differences in posttest performance that other variables might not explain.

We chose as our pretest a part of the Comparative Guidance and Placement Program (Educational Testing Service, 1973). This program offers a wide range of services to community colleges. It has a biographical inventory, a comparative interest index, and eight tests especially designed to help counselors or faculty advise students. One college involved in the TICCIT project had earlier participated in the program and the other was receptive to use of the program's math tests. We recommended Part 1 and Part 2 from Level D of the CGP math tests. Each of these two sections takes about twenty minutes to complete and has thirty-five questions. The first part covers computational skills: arithmetic operations with whole numbers, fractions, numbers with decimal values, and percentages. The second places emphasis on relations between quantities (i.e., equal to, greater than, less than), but students must work with unknown terms from linear equations, exponents, quadratic expressions, and coordinate planes in order to answer the questions. This second section is a test of student readiness in elementary algebra.

The standardized pretest was administered on a trial basis in the second half of the 1973-74 academic year. Scores on the test appeared to reflect differences among students as well as differences across courses. At Phoenix the mean pretest scores were 35.11, 46.26, and 53.81 across their introductory, intermediate, and college algebra course sequence. The standard deviation within each course fell close to ten points, based on sample sizes of 267, 253, and 125 students for the three courses, respectively. Thus the CGP pretest was sensitive to student differences, as judged by the size of the standard deviation, and to differences in students' math background, as indicated by the jump in the average score through the algebra sequence. Data collected at Alexandria confirmed this evidence for the CGP test's appropriateness in the evaluation. There we tested students at the start of three distinct course sequences: Algebra I; General College Mathematics I; and College Mathematics I. As expected, the pretest mean was lowest for the least stringent sequence in terms of prerequisite high school mathematics and highest for the sequence that required the most high school background. In Algebra I the mean was 34.67 while in College Mathematics I it was 48.99. Again the standard deviations were in the neighborhood of ten points. An estimate of pretest reliability gave an internal consistency index of .92. This estimate was drawn from 863 pretests taken in the fall semester of 1974 at Phoenix. It is comparable to the reliability estimate reported in the CGP technical manual, .89 (Educational Testing Service, 1973). We were well-satisfied that the CGP provided a valid and reliable pretest for our evaluation.

The preparation of posttests followed from the development of an extensive item pool. The first courses scheduled on the TICCIT system corresponded to units 14 through 23 of the math courseware (see Figure 1.3 in Chapter 1 or Appendix A). So our examiners developed two or three test questions for each segment in these units. The item pool consisted of over 250 test questions. There were multiple-choice as well as open-ended questions. We had decided that a multiple-choice format, despite its concomitant ease of scoring and processing, placed an unnatural constraint on student responses in final exams. Math instructors tended to use open-ended problems for their final exams and urged us to do likewise in the posttests. Of course we wanted our posttests to be adopted as departmental final exams (in the belief that this would constitute a strong argument for their content validity) and therefore offered a compromise solution with both formats.

Instructors at the colleges reviewed the item pool in blocks of questions grouped according to their courses. While the ten courseware units represented TICCIT's algebra course, they in fact corresponded to five different courses at the community colleges. There was a group of potential test items for each of the five courses, with considerable overlap among the groups. It is easiest to illustrate this point: Figure 2.1 represents the match between TICCIT units and college courses as proposed early in the project. Units 14 through 22 account for nearly all the material in Math 007, 106, and 108 at Phoenix and Math 31 and 181 at Alexandria. Instructors told us whether an item was appropriate for one of these courses, needed revision before further consideration, or was unacceptable. From their item reviews and suggestions for additional questions (where regular class coverage extended beyond that of TICCIT courseware), we developed the first versions of posttests.

These first posttest forms were not the last. In general there were three versions of each test, and four versions were required in isolated cases of repeated curriculum changes. We made these revisions in order to accommodate instructors' recommendations for fair tests as well as to improve the tests with the benefit of item data. For example, one course stressed factoring and instructors pointed out that our posttest was inadequate in its emphasis on this aspect of the course. So we adjusted the number of test items to reflect course emphasis as well as coverage. There were also some questions deleted from the posttest. Particularly those items on arithmetic operations with positive and negative whole numbers, such as $14 \div (-2)$ or $3[25-9(2)]$ or $2(-6)$, proved to be too elementary. Nearly all students gave correct answers to such questions. We also found consistent low item difficulties for questions about simple set-subset relations and therefore deleted these questions as well.

To illustrate the type of items on the posttest two problems from an intermediate algebra test appear in Figure 2.2. The multiple choice problem also serves as an example of what kind of revisions were made to improve individual

TICCIT Math Units and Community College Courses

Unit Number	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Number of Lessons	4	4	2	2	3	6	3	5	4	6	4	2	4	2	5	4	4	2	3	4	3	4
College Courses																						
Phoenix																						
Math 007 Beginning Algebra																	X			X	X	X
Math 106 Intermediate Algebra														X	X	X	X	X	X			
Math 108 Fundamentals of Algebra														X	X	X	X	X	X	X	X	X
Math 117 College Algebra	X	X					X	X	X	X	X		X					X				
Math 118 Plane Trigonometry			X	X	X	X			X													
Alexandria																						
Math 31 Algebra I																X	X	X	X	X	X	X
Math 32 Algebra II							X	X	X	X	X			X	X							
Math 38 Trigonometry			X	X	X	X																
Math 181 General College Mathematics I												X				X	X		X	X	X	
Mat 182 General College Mathematics II									X	X	X		X		X	X		X				
Math 183 General College Mathematics III	X				X	X	X							X								

Figure 2.1

test items. Originally that problem called for an ordered pair (x,y) as a solution to the two linear equations. But with alternative pairs given as response choices, a student might solve the problem by simple substitution. The revision discourages this method of solution. The other problem represents the type of open-ended questions used in the posttests. This particular item was an addition made to reflect course emphasis.

Field trials for all tests except those on retention were held in conjunction with the first use of the TICCIT system for teaching algebra courses. But these trials had been preceded by test administrations focused on refining items. So the 1974-75 test forms already incorporated revisions based on earlier data collection. The length of posttests then ranged between 54 and 64 separate items, with each multiple-part problem counted as several items. The two topical tests, one on linear equations and another on algebraic expressions, had 25 and 26 items respectively. Internal consistency estimates of posttest reliability came to an average of .84 in the fall academic term. After we made some minor changes and shortened forms by about three items per test, the average in the spring term was .89. Reliability of the topical tests averaged .88 for the same academic year.

Test reliabilities for the 1975-76 academic year appear in Tables 2.1 and 2.2. This period was the demonstration phase of the TICCIT project for community college math. The figures in these tables apply to the data reported later (see Chapter 5: Student Achievement) as part of our evaluation of the impact of the TICCIT program on student achievement.

As expected, the standardized pretest, identified as test form 601 in Table 2.1, has a high reliability. The course-specific pretests, forms 622, 623 and 624, were constructed to meet our dual need for a measure of retention from a

Examples of Problems from Math Posttests

Multiple-choice Format:

19. If $2y=4$ and $x+y=6$, then $x-y=$

    (A) -6 (B) -2 (C) 2 (D) 6

Open-ended Format:

44. Factor completely each of the following.

    (A) x^2-25y^2

    (B) $2x^2-x-6$

    (C) $5-20x^2$

    (D) $49x^4-25x^6$

Figure 2.2

Pretest Reliability: Internal Consistency Estimates
Alexandria and Phoenix
Mathematics Courses
Calendar Year 1976

Academic Term	Course	Test Form	Number of Students	Total Number of Items	r
Fall Semester	Math 007	601	422	70	.92
	Math 106	601	180	70	.92
	Math 108	601	133	70	.92
Spring Semester	Math 007	601	332	70	.91
	Math 106	622	229	20	.70
	Math 108	601	153	70	.91
	Math 117	623	150	20	.77
Fall Quarter	Math 31	601	221	70	.90
Winter Quarter	Math 32	624	44	20	.72
Spring Quarter	Math 31	601	130	70	.92
	Math 32	624	75	20	.66
	Averages:	601		70	.91
		622, 623, and 624		20	.71

Table 2.1

Posttest Reliability: Internal Consistency Estimates
Alexandria and Phoenix
Mathematics Courses
Academic Year 1975-76

Posttests:

Academic Term	Course	Test Form	Number of Students	Total Number of Items	r	Items for Common Objectives	r
Fall Semester	Math 007	614	182	57	.92	48	.91
	Math 106	618	101	49	.85	43	.84
	Math 108	619	54	56	.88	50	.87
Spring Semester	Math 007	614	181	57	.86	48	.86
	Math 106	615	108	55	.86	48	.85
	Math 108	616	55	61	.85	55	.85
	Math 117	626	71	46	.90	38	.90
Fall Quarter	Math 31	609	122(105)[1]	54	.90	44	.90
Winter Quarter	Math 31	609	113(80)[1]	54	.91	44	.92
Spring Quarter	Math 31	609	79(41)[1]	54	.94	44	.93
	Math 32	627	92[2]	41	.86	34	.85
			Averages:	53	.88	45	.88

Topical tests:

Linear Equations -					
Fall Quarter	Math 31	617	77	22	.81
Winter Quarter	Math 31	617	77	22	.84
Spring Quarter	Math 31	617	57	22	.82
Spring Semester	Math 007	607	80	26	.80
Algebraic Expressions -					
Spring Quarter	Math 32	608	55	25	.76
Spring Semester	Math 108	608	49	25	.85
			Averages:	24	.81

---

[1] While the reliability estimate for total score is based on all posttests, that for objectives common to TICCIT and lecture conditions excludes posttests taken in programmed instruction classes. Thus there is a lower number of students for these estimates of consistency on Math 31 common objectives.

[2] Estimates for Math 32 include data from both the winter and spring quarters. The number of students completing this course in the winter prevented separate analyses for each term.

Table 2.2

prior course as well as a measure of student preparation for the next course in an algebra sequence. For both purposes a test of what a student had learned in the prerequisite course seemed reasonable, and one test instead of two was always desirable so as to reduce the evaluation's interruption of teaching activities. The average reliability of these course-specific pretests falls below that of the CGP Math D test. However, test length perhaps explains this difference. There were only twenty items in each course-specific pretest.

Table 2.2 presents reliability estimates for all posttests and topical tests used to assess student achievement. The high posttest reliabilities seem to reflect the care taken in their preparation. The actual analyses of posttest results rely on those items for objectives shared by the classroom and TICCIT conditions. So the table also reports reliabilities for each posttest based only on these common objectives. There is hardly a difference between test reliability for total score and that for common subscore, probably because at least four out of every five items tested a common objective. For the topical tests the average reliability was satisfactory despite the low number of items. The discrepancy between course-specific pretest reliability and this average for topical test might be attributed to the breadth of test coverage. While pretests spanned an entire term of material in just twenty items, topical tests focused on one particular component of a course and thus covered about one-fifth as much material with an equivalent number of items. Their limited content coverage certainly contributed to the consistency of topical tests as achievement measures.

The two reliabilities for each posttest, one for total score and another for the subscore based on common objectives, suggest the importance of item classification and perhaps raise the issue of test validity. It was the math faculty at the demonstration sites and the courseware authors who determined whether an item was related to their instructional objectives. We simply took both sets of reviews and established four categories for each course's objectives: (1) objective common to both lecture and TICCIT coverage; (2) objective unique to the curriculum in regular classes; (3) objective unique to the TICCIT courseware; and (4) objective beyond the scope of the instructional programs. This classification scheme for objectives helped us to avoid measures of results with undue emphasis on one curriculum or the other. And our analyses of achievement results did use common scores as the basis for comparisons between program outcomes.

Even with comparisons confined to objectives shared between programs, it was possible that the TICCIT program would lead to patterns of math achievement different from those of lecture classes. So we classified each test item by ability level and content category as well as objective. This classification scheme made it easier to detect finer, albeit less reliable, differences in program outcomes. Such detail was consistent with our intent to document TICCIT's strengths and weaknesses, and to present evaluative information useful in making decisions about program adoption or refinement.

The categories for classifying posttest items appear in Figure 2.3. The ability levels closely follow those used for standardized testing programs, for example the Sequential Tests of Educational Progress (Educational Testing Service, 1971). A question for factual recall typically called for use of a definition (e.g., "Which of the following is a natural number?" or "List the first five elements in the set of even integers greater than 0."). Manipulation commonly involved arithmetic computation (e.g., "In its simplest form $\frac{12}{54}$ = _____." or "Work each of the following and write the result as a rational number in its

Item Classification for Mathematics Posttests

Categories:

Objectives

1 - objective common to both lecture and TICCIT coverage

2 - objective unique to curriculum in regular classes

3 - objective unique to TICCIT courseware

4 - objective beyond the scope of the instructional programs

Ability Level

0 - factual recall

1 - manipulation

2 - solution of routine problems

3 - demonstration of concept comprehension

Content Category

1 - arithmetic

2 - algebra

- (a) simplifying, including properties of and computations with signed numbers and complex numbers
- (b) equations, including substitutions, equivalent equations, solution of equations, and word problems
- (c) exponents, radicals, and logarithms
- (d) factoring, multiplying, and dividing algebraic expressions including quadratics
- (e) number line and coordiante plane
- (f) inequalities, absolute value, and sets including solution sets
- (g) sequences, arithmetic and geometric progressions
- (h) permutations and combinations, binomial theorem

Figure 2.3

simplest form: (A) $\frac{3}{4} + \frac{1}{5}$, (B) $\frac{12}{25} \times \frac{5}{6}$, (C) $10 \div \frac{2}{5}$."). The open-ended problem given in Figure 2.2 illustrates the kind of item considered as belonging within the level for solution of routine problems. To be classified as an item that tapped demonstration of comprehension of a concept, a question had to go beyond the bounds of the routine problems encountered in a course. Such problems required that students apply familiar rules in an unfamiliar context. For example, although students had worked with word problems in beginning algebra courses, these problems were not as straightforward as strictly numerical systems of linear equations. So word problems such as

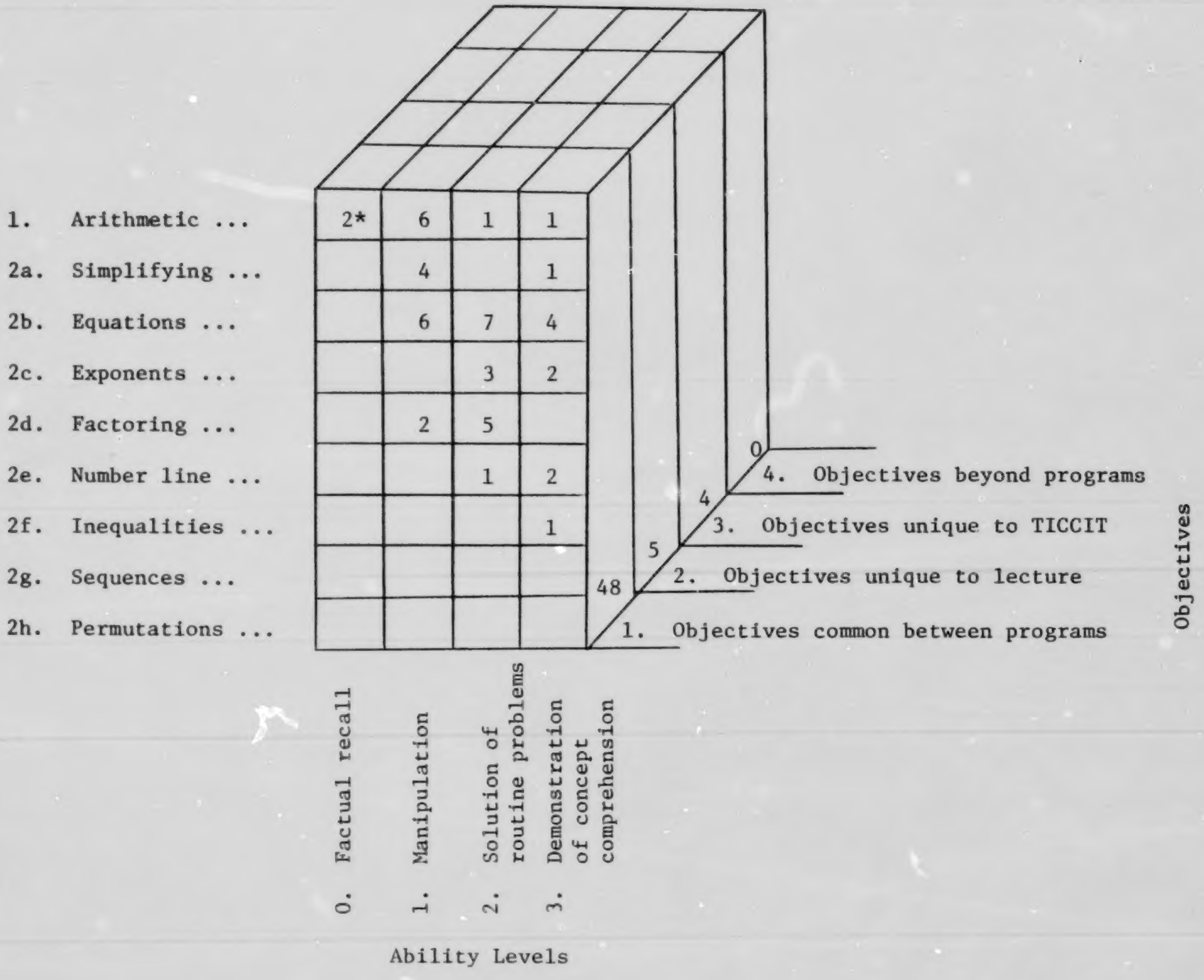
> Tanks P and Q together hold 630 gallons of gasoline. If tank P holds 150 gallons more than tank Q, how many gallons does tank Q hold?

and other problems that involved combinations of rules (e.g., "If $2^4 \times (2^2)^5 = 2^x$, then x = _____.") and therefore presented otherwise routine concepts in unfamiliar situations, came under the ability level for demonstration of concept comprehension.

The examiners responsible for preparing posttests established the content categories from inspection of the posttest items. As might be expected these content categories conform fairly well to the courseware units and textbook chapters. And since they correspond to traditional topics the scheme is probably self-explanatory.

The result of the three dimensions for item classification is a posttest breakdown such as that depicted in Figure 2.4. This gives the number of test items within each cell of the classification scheme. It should be apparent that too few items fall within a cell for the purpose of making comparisons between programs. Instead we relied on the marginal totals when looking at results across programs. As with the analyses of overall achievement effects, only those items on common objectives went into the subscores for the four ability levels and

Example of Item Coverage
for Math Posttests



	0. Factual recall	1. Manipulation	2. Solution of routine problems	3. Demonstration of concept comprehension
1. Arithmetic ...	2*	6	1	1
2a. Simplifying ...		4		1
2b. Equations ...		6	7	4
2c. Exponents ...			3	2
2d. Factoring ...		2	5	
2e. Number line ...			1	2
2f. Inequalities ...				1
2g. Sequences ...				
2h. Permutations ...				

Ability Levels

Objectives

0 4. Objectives beyond programs

4 3. Objectives unique to TICCIT

5 2. Objectives unique to lecture

48 1. Objectives common between programs

---

*Number of items from beginning algebra posttest that fall within each cell.

Figure 2.4

the nine content categories. Of course not all subscores existed for each posttest. The beginning algebra test had no items on sequences or permutations, while that for advanced algebra had none on arithmetic. Complete item classifications for the posttests appear in Appendix C. These should both demonstrate posttest validity through matches with the course coverage and convey some idea of the applicability of our results to other community colleges' courses.

Perhaps the best evidence of validity for our math achievement tests comes from the manner in which the colleges used them. The math department at Phoenix adopted them as their final exams and determined students' grades, in part, by their score on our posttests. The algebra courses at Alexandria had simple pass-fail grades dependent on whether a student finished a course and how much progress he had made in the course. Our posttests, then, did not contribute to student grades at Alexandria. But when a major curriculum change forced the college to try the TICCIT program for another, comparable course sequence, the math department chose to use our posttests as achievement measures in their own study of student performance.

Achievement Tests: English. The process of test preparation for courses in English composition was quite different from that for math courses. There is, after all, a marked contrast in the subject matter. Although an item classification scheme might reveal much about the curricular emphasis of a math course, it tells us little about composition courses where the primary concern is student writing. We took essay samples from students as the most direct measures of achievement in composition courses. Since certain types of objective items show a strong relationship to writing ability, we also developed tests of composition skills in a multiple-choice format.

The TICCIT system first supported courses in English composition in the summer term of 1975. Almost three years earlier we had reviewed initial courseware specifications. It was so difficult to transfer a traditional and sound English curriculum to a mainline format that there were serious schedule slippages in courseware production and significant changes to the content specifications. The developers of the TICCIT program also went through unexpected professional disputes among their composition authors and with college instructors in attempting to define an optimal course on writing. Of course this affected our schedule for instrument preparation.

If we had waited until the TICCIT program supported composition classes, the time span before the demonstration phase would have been too brief for instrument development and field trials. We began preparing appropriate tests in the winter of 1974. From visits to the colleges in the preceding year it had become clear that only an essay sample would lead to a consensus among participants on testing. Examiners with backgrounds in English test development met with instructors and encouraged them to submit suggestions for appropriate essay topics.

Nearly fifty recommendations were sent to us from the colleges. From these we selected ten as possible topics that would be familiar enough to all students for them to write under time constraints. A list of these topics, slightly revised so as to conform to a testing situation, was then returned to the colleges. Toward the end of the spring term of the 1973-74 academic year instructors cooperated with the evaluation by collecting student responses to the topics. These writing samples constituted the data base which determined the pretest and posttest essay topics. Of course data or writing samples themselves do not determine topics. Rather instructors scored the samples at sessions conducted by our examiners and then we chose topics for certain characteristics.

But what criteria do instructors consider in assessing the worth of a student's writing? This question was pertinent to understanding scores assigned to essays and to developing objective tests of writing skills. So prior to holding scoring sessions and discussing multiple-choice test formats, we distributed a very short questionnaire to members of the English faculty at participating colleges. In fact the questionnaire had just one question: "How do you assess the worth of a student's writing? For which of the following do you tend to give credit?" The faculty response was remarkable: within three weeks 85% of the instructors had returned forms.

A summary of their responses appears in Table 2.3. Quite obviously logical organization and quality of thought represented important considerations in assessing student writing. Approximately half of the instructors further indicated that these two aspects of writing took precedence over other considerations in judging student essays. Close behind in importance were correctness of expression and unity. It is interesting to note that, despite differences in teaching composition skills, there was a consistency in judging student writing both within a college and between colleges. Perhaps this consistency and the distribution of responses across various aspects of writing will ease others' concerns about what criteria faculty applied in scoring our essay pretests and posttests.

At the sessions held in the spring of 1974, instructors assigned scores on a scale of one to four points. Such a holistic scale may seem too narrow in range for assessing student writing. Actually, though, our purpose was evaluating a curricular program. And a range of four possible choices contributed to the

Aspects of Writing:

Faculty Considerations in Rating Student Essays

	Alexandria		Phoenix		Total	
	Frequency	Percent	Frequency	Percent	Frequency	Percent
Number of respondents	15	100	19	100	34	100
Aspects of Writing						
Sophistication of vocabulary	8	53	11	58	19	56
Originality of expression	12	80	12	63	24	71
Expression of writer's personality	6	40	7	32	13	38
Quality of thought	15	100	19	100	34	100
Sophistication of sentence structure	13	87	15	79	28	82
Awareness of situation and audience	11	73	15	79	26	76
Correctness of expression	15	100	18	95	33	97
Logical organization	15	100	19	100	34	100
Expression of feeling	8	53	7	32	15	44
Sincerity of expression	9	60	12	63	21	62
Economy	10	67	13	68	23	67
Unity	14	93	18	95	32	94
Other						
thesis statement			3	16		
support of theme			3	16		

Table 2.3

reliability of essay scores. A wider spread of possible scores would make it more difficult to reach a consensus on the appropriate score for sample essays, a necessary preliminary step in the scoring sessions. Several hundreds of writing samples were scored in the pilot testing for essay topics.

From the topics tried at the colleges we selected one as a pretest and another as a posttest. These selections were based on the distribution of scores, the frequency of score discrepancies, and comments made by the instructors about student responses. We wanted an essay topic familiar enough to students for them to be comfortable in writing an essay within twenty minutes. Yet we also wanted topics that would reflect differences among students. So we looked for a spread in the distribution of scores. Since two instructors read each essay, it was possible that a topic might be particularly susceptible to divergent scores. Such a topic would not be suitable for the evaluation. Therefore we chose topics with a minimum number of score discrepancies. Finally, instructors contributed to our decision about essay topics through their comments about students' reactions to the task in classes as well as the quality of their students' papers.

The essay topics for pretesting and posttesting appear in Appendix D. These were subject to additional field trials in the fall term of the 1975-76 academic year. Over 2700 students responded to them in the 1976 calendar year, the demonstration period for the TICCIT program in English composition courses. When data collection came to a close, scoring sessions were again held at the colleges.

The reliability of the essay tests really depended on the extent of agreement between independent scorers. Table 2.4 presents the correlations between raters for the essays scored at Alexandria, and Table 2.5 for those scored at

Essay Test Reliability: Correlations Between Raters
Phoenix Scoring Session
English Courses
Calendar Year 1976

Pretest Essay

Posttest Essay

Rater		A	B	C	D	E	F	G	H	I	J	K
A	N		4	0	1	0	57	20	23	13	29	33
	r		—	—	—	—	.79	.49	.76	.88	.77	.67
B	N	2		4	0	2	38	0	13	26	26	30
	r	—		—	—	—	.63	—	.59	.72	.74	.69
C	N	0	0		0	0	12	35	24	11	43	31
	r	—	—		—	—	.77	.75	.66	.48	.69	.58
D	N	6	9	46		0	40	35	53	25	19	23
	r	—	—	.74		—	.70	.64	.72	.84	.68	.66
E	N	1	13	0	0		12	35	29	35	20	24
	r	—	.61	—	—		.61	.68	.73	.68	.70	.67
F	N	28	1	15	7	25		3	0	10	18	3
	r	.77	—	.66	—	.49		—	—	.75	.63	—
G	N	19	14	1	0	17	0		12	13	13	2
	r	.66	.77	—	—	.32	—		.71	.56	.52	—
H	N	19	1	20	0	11	7	12		12	5	0
	r	.72	—	.79	—	.79	—	.61		.73	—	—
I	N	22	27	11	0	16	0	0	2		0	0
	r	.61	.61	.51	—	.45	—	—	—		—	—
J	N	16	13	7	1	9	19	14	2	0		4
	r	.83	.10	—	—	—	.65	.68	—	—		—
K	N	0	0	0	29	8	8	0	26	0	12	
	r	—	—	—	.67	—	—	—	.75	—	.72	

Averages: pretest correlation .68
posttest correlation .63

Table 2.4

Essay Test Reliability: Correlations Between Raters
Alexandria Scoring Session
English Courses
Calendar Year 1976

Pretest Essay

	Rater		A	B	C	D	E	F	G	H	I	J
	A	N		25	26	31	42	[illegible]	[illegible]	17	33	12
		r		.84	.66	.72	.77	[illegible]	—	.80	.80	.77
	B	N	11		26	33	9	32	18	16	0	20
		r	.80		.73	.65	—	.71	.88	.80	—	.80
	C	N	28	14		7	9	25	29	23	16	29
		r	.74	.43		—	—	.64	.61	.84	.72	.71
	D	N	13	12	24		0	16	19	9	21	29
		r	.79	.50	.67		—	.65	.88	—	.71	.71
	E	N	12	1	12	13		2	23	15	0	9
Posttest Essay		r	.71	—	.91	.62		—	.62	.75	—	—
	F	N	13	26	14	1	0		9	26	17	19
		r	.68	.74	.27	—	—		—	.56	.55	.75
	G	N	24	30	14	0	13	2		10	21	8
		r	.76	.65	.64	—	.87	—		.17	.87	—
	H	N	9	0	0	21	0	0	0		1	10
		r	—	—	—	.65	—	—	—		—	.51
	I	N	0	0	12	12	1	23	0	12		7
		r	—	—	.79	.45	—	.54	—	.71		—
	J	N	1	2	0	0	12	14	0	26	29	
		r	—	—	—	—	.35	.86	—	.75	.79	
	K	N	10	12	12	0	12	13	5	0	0	12
		r	.79	.84	.72	—	1.00	.76	—	—	—	.38

Averages: pretest correlation .71
posttest correlation .68

Table 2.5

Phoenix. Raters (instructors in the English departments at the respective colleges) were unaware of where essays had been written or from which class essays had come since all identifying information had been masked on the student papers. Still, it was possible that some instructors recognized the pretest and posttest topics from test administrations in their classes. Indeed it did seem that some instructors employed stringent standards for the highest score on posttests. This might account for the slightly lower correlations between raters on posttest essays than on pretest essays.

The average inter-rater correlations, despite a range from .10 to 1.00, fall within reasonable limits for this type of judgment reliability. A reliability of .67 or so might be low in comparison to the internal consistency estimates for math tests, but represents a satisfactory level consistent with our experience in essay scoring. We had taken precautions to guard essay reliability. Whenever raters disagreed by two or three points in scoring a paper, those scores were discarded and two other raters read the paper. The incidence of such discrepancies was very low: fewer than six percent of the essays had to be reread. And the second pair resolved all but about a dozen of the discrepancies. With regard to the consistency of scores assigned at the two sessions, raters at Alexandria and Phoenix went through the same sample of student papers before actually grading. The correlation between the two sets of scores was .96 for the pretest essay and .84 for the posttest essay. These coefficients seem to justify our treatment of scores as if assigned by one group for all essays.

The item types in the objective tests were among those with the strongest relationship to the criterion of actual writing. Godshalk, Swineford, and Coffman (1966) reported the correlations for the two major types that appear in our tests as .70 with student essays. This was the primary reason behind our decision to use these item formats, for there had to be evidence of a relationship to writing if instructors were to accept objective tests as appropriate for composition courses.

Figure 2.5 gives examples of the item formats from the objective tests. The first type requires the ability to recognize writing that does not follow the conventions of standard written English. Such items accounted for over 60% of the objective tests. Another fourth of the tests consisted of items similar to the second type shown in Figure 2.5. These require recognition of improper writing as well as sufficient writing skill to choose a clear and precise manner for rephrasing sentences. In the last type of item students had to join phrases together and thus decide about relative detail and logical connectives in sentences. These, too, correlate highly with actual writing, but not to the same extent as the preceding two types (see Godshalk, Swineford, & Coffman, 1966). And so such items amounted to just one-eighth of the objective pretest and posttest.

The item format may tell something about the ability tested, like the item classifications for math posttests according to ability level. It omits information comparable to that given by the content categories for math posttests. It should be clear that our foremost concern in testing was assessing students' writing. Coverage of specific grammatical points or particular structural conventions was secondary. However, a breakdown of pretest and posttest coverage may be found in Appendix E. At the item level it is apparent that the objective tests tap traditional points in writing: subject-verb agreement, pronoun reference, adjective-adverb confusion, verb form and other skills.

Examples of Item Types from Objective Tests of Writing Skills

I. **Directions**: In each of the following sentences find out what is wrong, if anything. In deciding whether there is something wrong with a sentence, consider the way a sentence should be written in standard written English, the kind of English usually found in textbooks. Remember that this is sometimes different from the kind of English that we use in talking with our friends.

Some sentences are acceptable without change.
No sentence contains more than one error.

If the sentence has an error, you will find that the error is underlined and lettered. Assume that all other parts of the sentence are acceptable and cannot be changed.

When you find an error, select the one underlined part that must be changed in order to make the sentence acceptable, and blacken the corresponding space on the answer sheet.

If there is no error, mark space E.

ANSWER

4. Many of his admirers believe that Vonnegut sees life in the same way
A B C
as them. No error
D E

A
B
C
■
E

8. Washington successfully attacked the Hessians at Trenton and demonstrating to the British that the Colonial Army was still strong. No error

A
■
C
D
E

Figure 2.5(a)

Examples of Item Types from Objective
Tests of Writing Skills

II. **Directions**: In each of the following sentences some part of the sentence or the entire sentence is underlined. Beneath each sentence you will find four ways of writing the underlined part. The first of these repeats the underlined part in the original sentence, but the other three are all different. If you think the original sentence is better than any of the suggested changes, you should choose answer A; otherwise you should mark one of the other choices. Select the best answer and blacken the corresponding space on the answer sheet.

In choosing your answers, follow the requirements of standard written English, the kind of English usually found in textbooks. Remember that it is sometimes different from the kind of English we use in talking with our friends. Pay attention to how clearly ideas are expressed, whether the words convey the meaning they are supposed to convey, and how the sentence is constructed and punctuated. Choose the answer that produces the most effective sentence--clear and exact, without awkwardness or ambiguity. Do not make a choice that changes the meaning of the original sentence.

ANSWER

27. An antipollution act intended to protect Delaware Bay was passed by 🄰
the state legislature, which the governor signed. 🄱

(A) was passed by the state legislature, which the governor signed ■

(B) was passed by the state legislature and then the governor signed it 🄳

(C) was passed by the state legislature and signed by the governor 🄴

(D) and which was passed by the state legislature, was signed by the governor

(E) and passed by the state legislature, was signed by the governor

III. **Directions**: These questions ask you about words used to connect ideas in sentences. You are to choose the best word or phrase to use to join the ideas in the sentence marked I to the ideas in the sentence marked II; that is, you are to choose the word or phrase that will make the most sense in a new sentence that combines sentences I and II. Some sentences will have to be changed only a little; others will have to be changed a great deal.

37. I. Sarah heard about the tire sale. 🄰

II. Sarah left to buy new tires. 🄱

(A) As if 🄲

(B) Nevertheless 🄳

(C) However ■

(D) Despite

(E) As soon as

The new sentence is "As soon as Sarah heard about the tire sale, she left to buy new tires." or "Sarah left to buy new tires as soon as she heard about the tire sale." Answer (E) should therefore be marked.

Figure 2.5(b)

Although the objective tests were distributed for faculty and author review in the spring of 1975, there were few recommendations for revisions. As with the preparation of math tests, submitting specific tests for participant review had avoided unproductive requests for comment and encouraged constructive criticism. It also facilitated faculty cooperation and contributed to the tests' reliability and validity. Table 2.6 demonstrates this point: the objective tests of writing skills had respectable coefficients of internal consistency. The estimates in this table cover the demonstration period for the TICCIT program in English composition. For evidence of validity we again cite the instructors' decision to continue testing procedures established for our evaluation as part of their own study of the TICCIT program beyond the demonstration.

Student Attitudes. The final version of the student survey actually included questions about both students' attitudes toward a course and their activities related to the course. It had started as just a survey of student attitudes. Indeed the first draft circulated for review and piloted in late 1973 drew heavily from instruments concerned with student ratings of their instruction (e.g., Centra, 1972). It met with sound criticism from students, faculty, and administrators. There was too much emphasis on the instructor. In their comments about the questions, however, students within a class tended to make the same point. This suggested the power of one person's comment at the time of survey administration. Still the criticism was well taken: there was far too much about the instructor and there would be no counterpart for most of these questions in a survey meant for classes under the TICCIT program. And perhaps we had gotten too far ahead of the TICCIT program for it was still under development at this time.

Pretest and Posttest Reliability: Internal Consistency Estimates
Alexandria and Phoenix
English Courses
Calendar Year 1976

Academic Term	Course	Test Form	Number of Students	Total Number of Items	r
Spring Semester	English 019	701	165	40	.84
	English 029	701	118	40	.87
Summer Semester	English 029	701	74	40	.92
Fall Semester	English 019	701	327	40	.86
	English 029	701	152	40	.86
Winter Quarter	English 111	701	184	40	.85
Spring Quarter	English 111	701	312	40	.91
Fall Quarter	English 111	701	259	40	.86
	Average:	701	Pretest	40	.87
Spring Semester	English 019	702	89	40	.78
	English 029	702	58	40	.81
Summer Semester	English 029	702	41	40	.89
Fall Semester	English 019	702	231	40	.79
	English 029	702	87	40	.86
Winter Quarter	English 111	702	96	40	.84
Spring Quarter	English 111	702	248	40	.92
Fall Quarter	English 111	702	206	40	.84
	Average:	702	Posttest	40	.84

Table 2.6

We turned to studies about student attitudes toward computer-assisted instruction to find questions without as much emphasis on the instructor. What we found was the other extreme: either comparison between conditions was not part of the study's purpose (e.g., Summerlin, 1971) or the statements focused on CAI alone (e.g., Mathis et al., 1970). An instrument had to be prepared that would represent a compromise between ratings of instructors and general reactions to CAI. By the summer of 1974 installation of the TICCIT system had begun at the colleges and two parallel student surveys were sent to participants in the project for review. One form was intended for students in the TICCIT program and another for students in regular classes. Each form covered attitudes toward the course as well as activities related to it.

The reception and reviews for these two forms were favorable. It was necessary to make several statements more specific in reference to capabilities of the TICCIT system. Another refinement replaced the constructed responses about interpersonal contacts with a frequency scale for response since students balked at these questions in survey trials. Essentially these were the forms used in the second half of the 1974-75 academic year. The only additional changes before the demonstration phase of the TICCIT project involved improvements, primarily to the survey intended for lecture classes, so that statements would be identical or closely parallel across conditions.

The questions on the survey dealt with common claims about CAI, specific features of the TICCIT program, and general satisfaction with an instructional condition. Nearly twenty statements were the same across conditions or just rephrased to fit the condition. These constituted the basis for our comparisons of program results in terms of student attitudes. There were items about six specific features of TICCIT's instructional design, and about the classroom practices that best approximated five of these six. For example, practice problems ("PRACTICE") on the TICCIT system were likened to homework assignments in regular classes, and explanations available on the system ("HELP") to those given by an instructor. Other items simply repeated common assumptions about CAI advantages, about instruction that meets individual student needs or increases the amount of attention given individual students and so forth, and disadvantages, such as the impersonal nature of this method of instruction. Another group of statements pertained to reactions on a summary level. These posed questions on whether students would recommend the course to their friends or if they felt challenged to do their best work in the course. Such statements called for broad judgments of course quality and reflected overall satisfaction with a course. The actual survey forms for which we report data appear as Appendix F to this report.

It is difficult if not impossible to anticipate all student reactions with a finite set of questions. Just as the preparation of the student survey had benefited from casual conversations with students and their written comments on preliminary versions of the instruments, the interpretation of survey results might also benefit from informal contacts with students and further comment. Several statements on the survey forms, particularly those items specific to an instructional condition, had been suggested by students' comments--their wish for a textbook to use at home in TICCIT classes or the role of questions raised by other students in lecture classes. We did not want our reliance on an attitude survey to preclude comment on points omitted from the form but important to students. So we encouraged students to elaborate on their responses and comment freely and specifically on aspects of their course. Perhaps because it was a member of the evaluation team who administered the student survey, students provided extensive and meaningful comment. These will be presented in Chapter 6, Student Attitudes, along with the data from the item stems on the survey.

Table 2.7 gives internal consistency estimates, based on an alpha coefficient (e.g., Cronbach, 1970), for survey reliability in math courses. For each form of the survey the several estimates of reliability correspond to different scores. The total score is the sum of a student's responses to all attitudinal stems. The responses themselves had to be choices on a five-point scale of agreement (strongly agree to strongly disagree) or frequency (almost always to almost never). The surveys included stems phrased in a positive direction for which stronger agreement represented a more positive attitude. There were also stems worded in a negative manner. Such occasional shifts in stem direction were intended to discourage the formation of response sets or the simple repetition of a particular choice for all statements, and to foster consideration of each item as a separate statement. Of course we reversed responses to negative item stems in calculating scores, and excluded responses to stems of doubtful direction from the scores. This latter type of item was meant only as a source of information. The average reliability for total score, .90, is indeed respectable. But especially for an instrument designed to measure attitudes we should look at reliability in terms of scales.

The common score listed in Table 2.7 refers to a student's score on those items common across instructional conditions. These, once again, formed the basis for comparisons of program results. Without them there would be no standard for gauging whether a given attitude toward the TICCIT program was a positive or negative result in relation to usual practices. The average reliability for this score is again high, .88, as it should be since the common score includes almost all of the same items that determine reliability for total

Reliability of Student Attitude Survey:
Internal Consistency Estimates
Alexandria and Phoenix
Mathematics Courses
1975-1976

Academic Term	Survey Forms	Number of Respondents	Score	Number of Items	Internal Consistency r
Spring 1975	033-TICCIT	28	Total	24	.93
			Common	14	.90
	032-Lecture	190	Total	18	.87
			Common	14	.86
Fall 1975	035-TICCIT (Phoenix) 063-TICCIT (Alexandria)	144	Total	24	.92
			Common	18	.90
			Satisfaction	6	.88
			Attention	4	.75
			System Features	3	.72
	040-Lecture (Phoenix) 062-Lecture (Alexandria)	304	Total	21	.88
			Common	18	.87
			Satisfaction	6	.80
			Attention	4	.78
			System Features	3	.64
Winter and Spring 1976	069-TICCIT (Phoenix) 070-TICCIT (Alexandria)	205	Total	25	.91
			Common	19	.90
			Satisfaction	6	.86
			Attention	4	.72
			System Features	4	.71
	040-Lecture (Phoenix) 062-Lecture (Alexandria)	374	Total	21	.88
			Common	19	.87
			Satisfaction	6	.81
			Attention	4	.75
			System Features	4	.67

Table 2.7

score. Factor analyses of the fall and spring data from 1975-76 suggested that the common score actually consists of three separate scales (the analyses and scale descriptions appear in Chapter 6: Student Attitudes). These scales seem to reflect students' overall satisfaction with a course, their opinions about the attention given to them in the course, and students' reactions to specific features of the TICCIT system alongside other students' reactions to the counterpart of these features in the classroom. Despite the small number of items that constitute each scale, the average reliability estimate is .84 for the satisfaction scale, .75 for the attention and .68 for system features. These alpha coefficients for reliability, especially with regard to total and common scores, compare favorably with estimates reported in other studies of attitudes toward CAI (e.g., Brown, 1966; Williams & Milner, 1976) or student ratings (e.g., Costin, Greenough & Menges, 1971).

Since our comparisons of program results will be on the level of a course, it is also appropriate to report score and scale reliabilities for each course. Tables 2.8 and 2.9 give this information for math courses at Phoenix and Alexandria. These estimates appear to be consistent with those for all courses together. There is also new evidence of reliability given for classes at Alexandria. That college had sections of one math course under programmed instruction. The survey for this instructional condition was even closer to the form for the TICCIT program in that both were geared toward independent study programs and so shared a nearly identical set of item stems. Still the common score and subscales include only items shared by all three forms for TICCIT, programmed, and lecture classes. The survey form for programmed instruction has lower estimates of internal consistency than those for all courses taken together. But the slight difference is probably minor course fluctuation just like that for other courses taken one at a time.

Reliability of Student Attitude Survey:
Internal Consistency Estimates
Phoenix
Math 007, 106, 108, and 117
Academic Year, 1975-76

		TICCIT Classes					Lecture Classes					
	Score	Number of Items (Form 035)	Math 007 (N = 27)	Math 106 (N = 20)	Math 108 (N = 11)	TICCIT Total (N = 64)*	Number of Items (Form 040)	Math 007 (N = 134)	Math 106 (N = 73)	Math 108 (N = 38)	Math 117	Lecture Total (N = 260)*
Fall	Total	24	.93	.91	.94	.92	21	.87	.85	.87		.88
	Common	18	.92	.87	.94	.91	18	.86	.84	.86		.87
	Satisfaction	6	.91	.39	.92	.89	6	.77	.77	.83		.80
	Attention	4	.79	.43	.80	.73	4	.80	.66	.72		.77
	System Features	3	.68	.80	.54	.68	3	.53	.66	.66		.62
		(Form 069)	(N = 20)	(N = 11)	(N = 15)	(N = 54)*	(Form 040)	(N = 121)	(N = 81)	(N = 37)	(N = 50)	(N = 289)
Spring	Total	25	.94	.92	.90	.92	21	.89	.88	.82	.89	.88
	Common	19	.94	.91	.88	.91	19	.89	.87	.81	.88	.87
	Satisfaction	6	.90	.88	.83	.86	6	.84	.81	.81	.81	.82
	Attention	4	.50	.78	.64	.63	4	.73	.75	.70	.72	.73
	System Features	4	.82	.71	.59	.70	4	.67	.71	.54	.65	.67

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*Totals for lecture and TICCIT classes include students from Math 117.

Table 2.8

Reliability of Student Attitude Survey: Internal Consistency Estimates
Alexandria

Math 31 and 32
Academic Year, 1975-76

		TICCIT Classes				Programmed Classes		Lecture Classes			
	Score	Number of Items (Form 063)	Math 31 (N = 46)	Math 32	Total (N = 80)*	Number of Items (Form 064)	Math 31 (N = 21)	Number of Items (Form 062)	Math 31 (N = 44)	Math 32	Total
Fall	Total	24	.90		.90	24	.92	21	.90		
	Common	18	.90		.88	18	.89	18	.89		
	Satisfaction	6	.88		.87	6	.84	6	.83		
	Attention	4	.73		.61	4	.75	4	.81		
	System Features	3	.82		.76	3	.80	3	.71		
		(Form 070)	(N = 64)	(N = 22)	(N = 109)*	(Form 064)	(N = 36)	(Form 062)	(N = 23)	(N = 20)	(N = 43)
Winter	Total	25	.88	.91	.91	24	.90	21	.87	.94	.91
	Common	19	.88	.89	.90	19	.87	19	.85	.94	.90
	Satisfaction	6	.82	.84	.87	6	.78	6	.71	.83	.78
	Attention	4	.61	.73	.68	4	.55	4	.78	.86	.82
	System Features	4	.69	.76	.72	4	.67	4	.77	.74	.76
		(Form 070)	(N = 24)	(N = 18)	(N = 42)	(Form 064)	(N = 38)	(Form 062)	(N = 12)	(N = 30)	(N = 42)
Spring	Total	25	.93	.85	.90	24	.91	21	.84	.85	.84
	Common	19	.92	.82	.89	19	.89	19	.83	.85	.85
	Satisfaction	6	.88	.78	.84	6	.78	6	.75	.70	.72
	Attention	4	.56	.71	.63	4	.77	4	.83	.68	.72
	System Features	4	.73	.43	.66	4	.52	4	.49	.57	.56

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*This number includes students who took Math 181 on the TICCIT system.

Table 2.9

The preceding estimates all dealt with math courses while Table 2.10 presents comparable data for English courses. Essentially the surveys were the same for both subjects. That intended for composition courses did include another two item stems: these required student judgments of the extent of their learning about grammar and composition. Whether the TICCIT program would promote just the learning of grammar and other basic skills without a concomitant increase in demonstrated writing ability was a central question to the English departments involved in the demonstration. And students' own judgments were important to the faculty as comfirmations of our objective and essay tests. The survey for English courses naturally referred to writing skills and other components of composition rather than mathematical rules or problems. The changes were minimal and thus the scales and reliabilities for the attitude survey in English courses run parallel to those in math. The common score again seems to include scales about course satisfaction, attention, and specific system features. And the reliabilities appear consistent with those for math.

Student Activities. The last section of each student survey concerned course-related activities (see Appendix F). To label all the questions in this last section as pertinent only to activities would be too restrictive. What several of the questions tapped might be interpreted as behavior indicative of affective reactions: plans for further academic work in the same subject (i.e., further courses in a math sequence or additional courses in composition or literature) and the appeal of a job related to the course. It is simply convenience and format that suggest we designate such questions as relevant to activities. Both course studies and employment entail future activity, and a simple dichotomous (yes/no) response accompanied these questions in contrast to the Likert scale that went with the stems of attitudinal statements.

Reliability of Student Attitude Survey:
Internal Consistency Estimates
Alexandria and Phoenix
English Courses
Calendar Year, 1976

		TICCIT Classes				Lecture Classes			
	Score	Number of Items (Form 068)	Spring Semester (N = 40)	Fall Semester (N = 100)	Across Terms (N = 140)	Number of Items (Form 067)	Spring Semester (N = 72)	Fall Semester (N = 161)	Across Terms (N = 233)
Phoenix English 19 and English 29	Total	27	.84	.87	.87	23	.92	.89	.90
	Common	21	.83	.87	.86	21	.92	.89	.90
	Satisfaction	8	.82	.78	.79	8	.85	.79	.81
	Attention	3	.73	.58	.63	3	.70	.77	.76
	System Features	4	.62	.73	.70	4	.66	.68	.68

		TICCIT Classes					Lecture Classes				
	Score	Number of Items (Form 066)	Winter Quarter (N = 52)	Spring Quarter (N = 58)	Fall Quarter (N = 101)	Across Terms (N = 211)	Number of Items (Form 065)	Winter Quarter (N = 45)	Spring Quarter (N = 140)	Fall Quarter (N = 63)	Across Terms (N = 248)
Alexandria English 111	Total	27	.91	.89	.89	.90	23	.91	.87	.90	.89
	Common	21	.90	.87	.88	.89	21	.90	.86	.90	.88
	Satisfaction	8	.80	.73	.78	.78	8	.80	.78	.78	.78
	Attention	3	.74	.75	.74	.74	3	.69	.67	.74	.70
	System Features	4	.83	.80	.72	.77	4	.80	.81	.77	.80

Table 2.10

There were just two other questions in the section of the surveys about activities. One multi-part question dealt primarily with the frequency of a student's interpersonal contacts related to the course. Its components covered discussions with classmates about course work, meetings with the instructor outside of class time about academic matters, attempts to obtain tutorial assistance and even the use of campus resources like the library. Another multi-part question required that a student estimate the number of hours per week that he had devoted to various course-related tasks, such as class time and homework assignments. Both of these last two questions plainly concern activities.

These few questions from the last section of the student survey constitute the extent of our study of student activities across instructional conditions. Obviously our intent was much more modest than that involved in the study of either achievement or attitudes. Yet students' plans for further course work and the attractiveness of a job related to the subject matter represented one dimension of the goals of the TICCIT program and so deserved to be checked at least at this minimal level of effort and cost to the evaluation. Similarly, critics often claim that CAI detracts from rather than enhances interpersonal contacts and this too warranted some independent check. The issue of student study time is not as minor. For time spent in learning bears on efficiency, theory and policy. If the TICCIT program did deliver instruction tailored to the individual student, it might precipitate a break with the academic term and enable some or most students to finish a course in far less time. This efficiency might in turn force a college to consider departures from the time constraints of an academic term, especially if there were a strong relationship between time and learning in the TICCIT program. Then too, there was the matter of what students actually did on a TICCIT system to take advantage of its learner control and what strategies for learning evolved.

Of the resources expended in documenting student activities most went toward defining what happened on the TICCIT system. A special report gave a history of each student's use of learner control for every lesson and unit in his course. It also recorded his performance on practice problems and the amount of time spent in every lesson. Regretfully these summaries proved to be unreliable: sometimes hundreds of access requests appeared where fewer than one hundred were possible. The fault might rest with the special computer program prepared independently of the system's developers, with lapses in the regularity of updates to the data base since these consumed much computer time, or perhaps early difficulties with the student records maintained on the system. Still, we will take advantage of these student histories to explore interrelationships among TICCIT features and to give a picture of the massive use of the TICCIT program that occurred on a course level.

Another report generated on the TICCIT system listed students' progress on a lesson by lesson basis. It had less detail than the report specially produced for the evaluation, but it was reliable. The weekly progress report had been designed and developed by the system's developers. Since it was intended as a management report for teacher use in counseling it was subject to instructors' scrutiny for accuracy. In the first term of the demonstration period there were inaccuracies and instructor criticisms. These subsided as corrections were made in the fall of 1975. Thereafter the last progress reports for an academic term became our source for data on time students spent on the system and on the number of lessons passed by each student. These data on time and mastery will be joined with our own pretest and posttest achievement scores in an attempt to look at time and learning on the TICCIT system.

Finally, we undertook direct observations of students studying on the TICCIT system. The observations concentrated on the extent, pace, and sequence involved in students' use of learner control. Particular emphasis was on the use of rules ("RULE"), examples of rule applications ("EXAMPLE"), practice problems ("PRACTICE"), and explanations available on the system ("HELP"). This also afforded an opportunity to document students' calls for optional system features, like management advice on how they might proceed with their study on TICCIT ("ADVICE"), as well as their requests for assistance from other students, proctors or instructors.

Over the spring and summer terms of 1975 the procedures for observing students went through a period of trial and refinement. By the fall the instrument was ready as well as explicit instructions for coding. Appendix G contains the coding form for observations of student interactions with the TICCIT system and the instructions. Since two different members of the evaluation team observed students working at terminals, both conducted a common set of observations as a check on inter-observer reliability. For the same twenty student sessions at terminals the observers assigned the same codes over 90% of the time. And nearly half of the disagreements were traced to an ambiguity in the instructions and resolved: one observer had counted all student use of system explanations while the other counted only that use associated with practice problems. Another quarter of the discrepancies in coding were due to one observer's "note pad" being the other's "work sheets" in checking materials present at a terminal. Details of these results appear in Appendix G along with the coding form and instructions. Results of the observations come in Chapter 7: Student Activities.

Student Characteristics. One last instrument pertinent to student performance served as a record of what variables students brought with them into the instructional conditions. Even if random assignment, blind section selection, or haphazard registration worked in our favor and resulted in roughly equivalent comparison groups, there was no guarantee that groups would still be equivalent at the end of the term. We thought it advisable, therefore, to introduce a check on enrollment procedures and gather data about student characteristics. At the very beginning of each terms we asked that all students in target courses complete a brief questionnaire (see Appendix H).

The questionnaire was prepared to find out why students chose a particular section of a course as well as get a profile of those students enrolled under an instructional condition. In documenting section selection we tried to discover whether anyone had recommended the particular teaching method to students and what reasons played important roles in students' decisions to enroll in a section (e.g., other sections already full, preference for a particular instructor). Also we wished to receive data on students' demographic characteristics. These data had two functions. The first was as a check for gross differences between comparison groups at the start of a course. But even gross differences uncorrelated with our dependent measures (completion, achievement, attitude) would not bias the results. It was important to have data on student characteristics not only as an initial profile of comparison groups but also as a means for making adjustments in our analyses and exploring possible program effects dependent on student traits.

The set of demographic variables included in our data base is admittedly a rather limited one. It covers high school and college grade point averages, number of college credits earned, type of high school preparation (i.e., general, vocational, academic, equivalency test), student status, employment commitment, age and sex. By design it does not contain variables on either socioeconomic or ethnic status. The student population at community colleges seems too heterogeneous for us to pose simple question about socioeconomic status, and the initial purposes of the evaluation bear no relation to ethnic status. In general, we tried to design an evaluation that would intrude as little as possible on the conduct of normal college services and the privacy of students and faculty.

2.2.b Faculty Acceptance and Teacher Role

The purposes of the evaluation were largely descriptive when it came to documenting the impact of the TICCIT program on faculty. We sought to describe what instructors did in TICCIT classes and how they reacted to the project. There were no comparison groups of instructors responsible solely for the TICCIT program or traditional practices. Such strict control over faculty would only confound those effects due to the programs with those due to different instructors. Instead instructors had a combination of classes, some under the TICCIT program and other sections in a lecture-discussion format. And hence, there will be no estimates of an effect on faculty in the same sense as an effect on students. The effects described here reflect TICCIT's impact on teachers and teaching as faculty attitudes toward the program and instructors estimates of their activities.

What differences there were in faculty exposure to the TICCIT program arose naturally from the project. Only instructors from the math and English departments actually participated in the TICCIT program since the target courses were in algebra and composition. Other faculty members, with the exception of the project directors at each college, had at best indirect involvement. While there would be thousands of students involved in the TICCIT demonstration, there would be at most sixty instructors. With so small a group and a number of diverse factors other than the evaluation to be considered in teaching assignments, there could be no comparison groups among faculty that would correspond to the teaching condition. Nor would such groups be appropriate given student performance as the foremost consideration in evaluating program results. But there would still be academic departments with different degrees of exposure and course sections under different instructional conditions. So it was possible to explore impact by looking at attitudes across departments and at teaching activities by type of section.

Even on a descriptive level our evaluation depends on some form of comparison. For faculty acceptance we can contrast attitudes toward CAI in general with later reactions to the TICCIT program in particular. This implies at least two surveys: one about CAI generally and another about the TICCIT program specifically. On each survey we can also examine opinions from the perspectives of different respondents such as administrators and instructors, or instructors responsible for students in the TICCIT program and others without such direct experience. This latter contrast along with changes in faculty opinions over time provides some evidence of TICCIT's impact on acceptance. For activities the contrasts follow from teaching assignments. Faculty estimated for each section the percentage of their time spent on various teaching duties. We can then take these estimates aggregated by type of section and compare an average distribution for a TICCIT class against that for a regular section.

These reactions to the program and estimates of time allocations represent judgments as much as impact. Indeed, there were no program outcomes with faculty in the same sense as outcomes like student achievement or course completion rates. The formation of opinions is part experience or knowledge about a program and part professional judgment that draws on other experience and knowledge. Decisions about devoting time to conflicting demands reflect student needs unfulfilled by a curricular program and instructors' judgments on how they might best meet such demands. Whether we should attribute attitudes and activities to impact of the TICCIT program or judgments of faculty perhaps depends on the extent of consistency in results across colleges and within subgroups (e.g., the math and English departments). Consistency would suggest impact free of differences due to individuals' judgments.

Special instruments best suited our purposes in describing attitudes and activities. But our decision to engage in further instrument preparation was as much a matter of necessity as of choice. A standardized survey would afford the advantages of norms and enable us to avoid preparing instruments beyond those required for students performance. A widely available questionnaire on faculty activities would probably provide reference points on practices followed elsewhere. There is, however, insufficient need for surveys or questionnaires about CAI and faculty acceptance or activities, and even less for instruments concerned with a specific program. Some special-purpose surveys did exist (e.g., Russell, 1969) but none that matched the context of the TICCIT demonstration well. That context involved teaching full courses by computers at community colleges, and it required that a faculty attitude survey and activity questionnaire be developed if the evaluation was to describe faculty acceptance and teacher role.

__Faculty Attitudes__. A description of the initial development and report of the first results from a faculty attitude survey appear in Alderman and Mahler (1977). That survey dealt with attitudes toward certain educational practices as well as computer-assisted instruction. However, there had been a low response rate to that survey and a few of the dimensions given for attitudes toward CAI seemed to be artifacts of item format. So another general survey was conducted in the spring of 1974, a year after the original. The revised instrument (see Appendix I) had fewer statements and concentrated on educational practices pertinent to the TICCIT program, such as mastery learning and self-paced instruction, and general assumptions about CAI, for instance its potential to tailor instruction for individual students. The return rate for this second survey was over twice as high as that obtained with the first: 76 percent of all faculty, or 239 persons, returned completed surveys. Perhaps the anonymous procedures for response and the shortened form (50 fewer questions than the original form) contributed to this improved rate of return.

A third survey, also in Appendix I, was sent to all faculty at the participating colleges during the first academic year of the demonstration phase for the TICCIT project. This was nearly two years after the successful general survey, and after more than four academic terms of faculty exposure to the TICCIT program for math courses (and just as composition courses on the system got under way). Essentially the items on this form were statements from the general version reworded so as to refer to the TICCIT program specifically along with several statements taken from the student attitude survey. This composition permits us to contrast general attitudes toward CAI with subsequent reactions to TICCIT, and to note a consensus or discrepancy between student and faculty perceptions. Over 200 faculty members again responded to our attitude survey.

Both the general and specific survey adhered to the item format used in collecting data on student attitudes. Each item was a statement accompanied by a five-point response scale for indicating extent of agreement. There were 30 such items on the general survey and 35 on the version about the TICCIT program in particular. The statements themselves reflected mostly positive attitudes toward CAI and TICCIT such as "TICCIT helps to make better and fuller use of instructors′ capabilities." There were also several statements phrased in a negative manner, "TICCIT is a potential threat to the jobs of faculty members." These intermittent reversals were intended to help respondents make distinctions among statements (and discourage response sets). But the section of the general survey that concerned educational practices really had no direction: we do not pretend to know positive from negative practices. Instead this section merely documented faculty opinions about concepts related to the TICCIT program. The specific survey also included a question about respondents′ experience with TICCIT. Through this question we could identify those instructors most familiar with the program and report their reactions apart from overall opinions at the colleges.

As with the student survey, estimates of reliability for the faculty attitude measures should refer to scales. The scales for which Table 2.11 gives internal consistency (alpha) coefficients correspond to the dimensions established through factor analyses. In the absence of extensive evidence for validity these scales merely represent a convenient shorthand for describing faculty opinions and drawing contrasts among groups of respondents. The statements encompassed by a scale and additional detail on the factor analyses may be found in Chapter 8: Faculty Acceptance and Teacher Role. It is sufficient now just to note the reliability estimates for the faculty attitude surveys: the

Reliability of Faculty Attitude Survey
Internal Consistency Estimates
Alexandria and Phoenix
1974 and 1976

Survey Form	Number of Respondents	Score	Number of Items	r
002-Initial Attitudes (1974)	209	Educational Practices	17	.61
		Student Focus	6	.62
		Subject Matter Emphasis	5	.61
		Receptivity	2	.71
		Incentives	3	.35
		Computer-Assisted Instruction	13	.85
		General	10	.88
		Familiarity	2	.83
003-Attitudes toward TICCIT (1976)	184	Familiarity	2	.72
		TICCIT	33	.93
		Global Judgments	18	.93
		Management	7	.78
		Limitations	4	.57
		Faculty Role	2	.53

Table 2.11

coefficient is high, as high as .93, except for those scales with very few items. A validity study for these scales was beyond the scope of our evaluation. However, the statements within each dimension and differences found among faculty members at least suggest that the dimensions represent meaningful constructs.

Faculty Activities. A questionnaire about faculty activities appears in Appendix J. The format and activity breakdown follow from those employed in an evaluation of another non-traditional college program (i.e., Hartnett, Clark, Feldmesser, Gieber & Soss, 1974). The questionnaire required instructors to report on their use of classroom hours as well as the distribution (in percentages) of their time spent in different activities. These hours and percentages were to refer to a regular work week in each section of a course. Thus instructors might complete from zero to five of these estimates depending on the number of sections of target courses each instructor had in an academic term. The responsibilities or activities listed in the questionnaire ranged from planning for class to counseling students and taking attendance, and included conducting class, preparing lectures and other duties associated with teaching.

There was a second part of the activity questionnaire unrelated to specific sections. It concerned general activities, such as advising student organizations or revising curricula or meeting for college committees, that might represent a significant redistribution of time as a result of the TICCIT program outside the confines of a section assignment for teaching. The questionnaire ended with a request that instructors indicate their perceptions of the relative advantages offered by the TICCIT program and regular practices for instruction, and a couple of questions about instructors' orientation to the TICCIT system.

The questionnaire on faculty activities was not a major part of our evaluation. It was meant only to describe what role instructors assumed with the TICCIT program as reflected in their own estimates of time devoted to classes on the computer system. As noted earlier in this section on instrument preparation for faculty attitudes and activities, these self-reports from instructors incorporate elements of impact and judgment. Another college's faculty might adopt procedures different from those at Alexandria or Phoenix. Maybe teacher role contributes as much to defining the context of the TICCIT demonstration as it does to documenting possible program outcomes. Indeed, we will refer often to the instructor's part in the TICCIT program in explaining results for student performance. Such reference is less a function of the instructor activity questionnaire than direct observation of comparison conditions and regular contact with instructors. Data from instruments may help us in identifying effects, but it is our knowledge of the full program conditions that helps in understanding what the effects mean.

2.3 Data Collection

Certainly the complications that might be expected in collecting data under field conditions arose. At one point in the evaluation forty posttests were mislaid for months and at another all pretests for one course were lost in the mail. The mislaid posttests were found filed, incorrectly, in a secure location at one college. As a replacement for the lost pretests we turned to records of test scores kept at the colleges. Then there were other obstacles to a truly planned experiment: a few members of the English faculty were reluctant to administer objective tests, and their reservations were strong enough to keep them from doing so during the demonstration; some part-time faculty were unfamiliar with the project and our data requirements and, hence, left inadequate class time for posttests or surveys. In short, the conditions that differentiate a field study from a planned experiment affected our evaluation. But these had a negligible impact and, we believe, even as a cumulative obstacle to data collection introduce no bias in our results.

These inevitable disruptions seemed to occur on the basis of a course section but our unit of observation was the student. Each individual student enrolled in a course on the TICCIT system went through a curricular program unique to that student. Because students could exercise control over various features of the TICCIT program and because computer systems do tailor instruction, the presentation of material varied by student. The unit of observation for the TICCIT program was clearly the student. Although other studies may use the classroom as the appropriate unit for lecture sections (e.g., Page, 1958), here it had to conform with the unit for observing outcomes under the alternative program.

This choice of the student as our unit of observation affected other activities in the evaluation. It meant that the student was also the unit for random assignment to conditions where we succeeded in arranging such procedures. Of course data collection and also analysis followed with the student as the appropriate unit. Thus when a student completed his work on linear equations, for example, it was time for him to take the topical test on that material. It happened that all students in a lecture section finished at the same time but rates differed for students in a TICCIT class. With regard to analysis it was the number of students, not sections or schools, that determined sample size.

2.3.a Sampling

In a sense there was no sampling for this evaluation. Data were to be collected on the performance of all students. But, except for completion rates determined by official grade sheets, this was impossible. Some students register for courses and then withdraw before attending a single class. Others start a course and fail to satisfy all requirements for receiving credit. Thus the number of pretests given in a class will be lower than the total student enrollment for that class, and the number of posttests lower still due to attrition and incomplete work. But of those students who received credit for a course, over 90% also took our posttest even where these tests were not adopted by department policy as final exams.

There were naturally exceptions to our otherwise successful data collection, and some affected the sample of students for whom complete data were available. Attendance, specifically absence of students at the time of pretest administration, caused the loss of a few cases of paired pretest-posttest observations from our achievement analyses. By far the greatest influence on our sample was what Campbell and Stanley (1963) call "mortality." Between the onset of instruction and the end of an academic term a sizable percentage of students fell behind in their course work and therefore received no credit and took no posttest. But this finding and the study of differential completion rates across conditions were part of the evaluation (see Chapter 4: Course Completion Rates). It is sufficient here to stress the importance of this aspect of student performance for its possible impact on other outcomes.

Experience during field trials did force us to reconsider sampling plans for the math courses at one college. The enrollment trend for one algebra sequence was on a steady and sharp decline. Further there was a poor overlap between objectives of the course as taught with the TICCIT program and in the classroom. This course sequence was dropped from the evaluation of the demonstration period for the TICCIT project. In another course sequence the initial enrollment together with the course completion rates left few students to represent program effects on their performance. So we decided to administer posttests to all students still attending classes at the end of a term, regardless of their probable completion status. This meant that even those students making insufficient progress toward course completion took the posttest. This may seem like an unreasonable population to study but there would be course grades to distinguish among groups (i.e., only those students who had received credit as opposed to all students regardless of grade) and these students gave us data on a broader population, in effect an estimate of overall program impact on student achievement within an academic term and independent of grades. The unacceptable alternatives were to risk inadequate sample size or not to evaluate the TICCIT math program at one site.

Generally, given those students who start a course and those who receive credit as the populations of interest, the samples in our evaluation constitute nearly the entire populations. Pretesting and posttesting became a part of the target courses. Instructors expected members of the evaluation team to come into their classes in order to distribute and collect attitude surveys at the end of a course. The cooperation of instructors at both colleges was clearly indispensable in this process, and their support of our data collection was exemplary. Faculty worked with us toward assigning students randomly to conditions and collecting data on student achievement and attitudes.

Observations of student activity and classroom conditions necessitated a much different form of sampling. The resource demands of observing students studying on the TICCIT system made us choose between tracking certain students throughout a course and trying to cover all students perhaps just once. Again experience from trials in the year preceding the demonstration guided our decisions. At each college representatives for the evaluator randomly selected about 80 students registered for the same course on the system. It took about two weeks to complete a cycle of observations and there were up to five observations on each student, dependent on his continued and regular attendance. These direct observations allowed us to watch for changes in students' use of the system over an academic term. Later access to online data summaries freed the evaluation staff for closer supervision of expanded data collection on student achievement and other duties. For they also observed each regular section of a target course once or twice in an academic term and each TICCIT class several times. There was no systematic basis for these class observations since they were intended to be descriptive.

2.3.b Schedule

Our sampling could take place only if the colleges decided to offer courses on the TICCIT system. In turn such college decisions depended on the availability of a fully operational TICCIT program. Obviously, then, the schedule for the evaluation was not ours to determine but instead followed from the colleges' activities and developers' progress. At first the colleges offered only a few course sections on the TICCIT system. This implementation phase of the TICCIT project served as a trial period for instruments and data collection procedures. As the colleges gained experience and confidence in the TICCIT program, additional sections were scheduled on the system, both in courses already attempted and new target courses. When nearly half of a course's total sections were on the TICCIT system the evaluation of program impact began.

The schedule for our data collection appears in Figure 2.6. At least one academic term of college exposure to a particular course on the TICCIT system always preceded our collection of data on program impact. This period of

Data Collection across Academic Terms

Course Number	Title	Phoenix Academic Year and Semester							
		1974-75			1975-76			1976-77	
		Fall	Spring	Summer	Fall	Spring	Summer	Fall	Spring
Math 007	Beginning Algebra	I	I	I	X	X	T	—	—
Math 106	Intermediate Algebra	I			X	X	X	—	—
Math 108	Fundamentals of Algebra	I			X	X	T		
Math 117	College Algebra				I	X	X	—	—
English 19	Basic English				I	X		X	—
English 29	Review of English Fundamentals				I	X	X	X	—

Course Number	Title	Alexandria Academic Year and Quarter							
		1974-75			1975-76			1976-77	
		Fall	Winter	Spring	Fall	Winter	Spring	Fall	Winter
Math 31	Algebra I	I	I	I	X	X	X	—	—
Math 32	Algebra II				I	X	X	—	—
Math 181	General College Mathematics I	I	I	I	T	—	—	—	—
English 111	English Composition I				I	X	X	X	—

I: Data collected in implementation period.

X: Data collected for evaluation of program impact.

T: Data collected in course sections on the TICCIT system only.

—: Continuation of college use of the TICCIT program beyond data collection.

Figure 2.6

adjustment separated our documentation of system installation and initial program trials (see Chapter 3: Implementation of the TICCIT Program) from our evaluation of results (see Chapters 4 through 7 on student performance). For math courses the demonstration phase of the project began with the fall term of the 1975-76 academic year; it commenced with the start of the 1976 calendar year for English courses. In general there were three academic terms of data collection on program results for each target course.

Nearly 200 sections of target courses were involved in the demonstration period alone. Others had been part of the instrument trials conducted during the implementation phase of the project. Within each section the timing for administering instruments was a direct function of the instrument's purpose. Pretests along with questionnaires on students' background characteristics (see Appendix H) were given at the beginning of an academic term. Sometimes pretesting was a part of student registration for target courses but usually it was done within the first week of classes. Likewise posttesting occurred during the last week of regular classes as well as the final exam period. However, students working on the TICCIT system generally took their posttest whenever they completed their course work rather than when the term ended. Pretesting and posttesting sessions were conducted under faculty supervision. Representatives of the evaluator supervised classes as students responded to the attitude surveys. Then there were topical tests administered by instructors as math students finished their study of certain units within a course, and summaries of student progress in the TICCIT program collected automatically by the computer system.

All of this testing and surveying amounted to an extensive data base on each student's performance. Even without the results of our observations, which were intended as supplementary descriptive information on class and student activity, there were enough variables to get an accurate and detailed account of program impact. Not all of the over 5,000 students enrolled in sections of target courses provided data for the evaluation: some withdrew without attending classes, others failed to satisfy course requirements within an academic term, and still others were in the few sections where data collection was disrupted. But nearly every student who started a target course became a part of our data base.

A summary of the data base accumulated for students appears in Figure 2.7. Complete information was not available for each student. It depended on whether he enrolled for a math or an English course, whether his section was a classroom format or one on the TICCIT system, and most of all whether or not he completed his course studies. At least for those variables that pertain to student characteristics (e.g., age or sex) it also depended on whether a student objected to answering questions of a personal nature. Obviously we had to rely on techniques of data analysis to make results clear from such a mass of variables.

2.4 Data Analysis

The approach we favor for data analysis differs somewhat from traditional methods. That is because both our view of program effects and our preference for reporting such effects follow slightly different lines of thought. The procedures themselves and the mathematical model underlying them, however, follow well known and accepted strategies for data analysis. It is in the interpretation of effects that the key difference lies.

We tend to perceive program effects as a difference. This should be obvious from our discussion of comparison groups and the care taken in developing fair measures of effects. But what does a difference between those outcomes obtained

Data Base on Student Performance

Background Measures and Demographic Variables

- Pretest on Computation and Algebra [Math]
- Essay Pretest [English]
- Objective Pretest on Writing Skills [English]
- College Grade Point Average
- College Credits
- High School Grade Point Average
- Type of High School Program
- Student Status (part-time or full-time)
- Extra-curricular Work (none, part-time or full-time employment)
- Prior Enrollment in Course
- Age
- Sex
- Predisposition toward CAI [TICCIT]

Measures of Program Results

- Course Completion (grade with credit)
- Posttest [Math]
  - Score on Common Objectives
  - Ability Subscores
  - Content Subscores
- Essay Posttest [English]
- Objective Posttest of Writing Skills [English]
- Topical Tests [Math]
- Retention Tests [Math]
- Attitude Survey
  - Score on Parallel Statements
  - Subscore for Personal Attention
  - Subscore for Satisfaction with Course
  - Subscore on System Features
- Activity Questionnaire
- Number of Lessons Passed [TICCIT]
- Time on Computer System [TICCIT]

Figure 2.7

with the TICCIT program and those with familiar classroom practices mean? Of course a significant difference is evidence of a program's effect. This seems only to suggest another question: How much of a difference need there be before it becomes an effect? Let us begin by considering what an effect is so that we can recognize one when it occurs.

Rubin (1974) defines a causal effect as the difference between what actually happened to a subject exposed to some treatment and what would have happened if the same subject had been exposed to some other treatment. He gives, as an example, "If an hour ago I had taken two aspirins instead of just a glass of water, my headache would now be gone" (p. 689). Thus the critical (but unmeasurable) quantity of interest is, for each subject, the difference between the value of an outcome under one condition and the value of the outcome under another condition. In other words, what relative benefit or detriment might be expected at the end of the academic term if we assign a student to a class on the TICCIT system instead of a regular class section?

In a sense this question points toward an unmeasurable effect: the difference in program outcomes for the same student. It is sufficient, for the moment, to note that this approach places emphasis on the difference in outcome measures between programs. And our analysis strategy leads to a direct estimate of this difference. The effects which we shall report will be these estimates: how much of a difference the TICCIT program made in terms of items on an achievement posttest, proportion of students completing a course, and extent of satisfaction with a course.

Certainly other approaches to data analysis might be advocated with equal conviction. It is not our purpose here to review their relative merits or even contrast alternatives with our approach. However, it would be a gross misinterpretation to view data presented in this report, specifically achievement data, as gain scores between pretest and posttest. Achievement tests were developed as measures of general background preparation and specific course learning, and their difference does not reflect gain. Given this caution, we wish only to explain the analysis strategy pursued for our evaluation in what follows.

2.4.a Assumptions

The general approach to the analysis consisted of estimating the parameters of a model as well as their standard errors and testing the statistical difference between appropriate parameter estimates. In order to specify the mathematical model that would allow such estimates and tests, we need to make several assumptions. Perhaps first we should understand that there is a specific population on which we base all our estimates and tests. This population (P) is the student body at the two demonstration sites, and, more specifically, those students enrolled in target courses for the TICCIT project. To the extent that these community college students resemble other populations, we can make generalizations to other contexts. But it was the students enrolled in algebra and composition courses at Alexandria and Phoenix from whom we collected data and for whom we estimated the effects of the TICCIT program.

Usually there is a well-defined experimental treatment and another that serves as a relative standard for comparisons or a control condition. In our case students took courses under the TICCIT program (T) or in a regular classroom (C). These were well defined instructional conditions in the sense that the TICCIT program has a consistent teaching strategy, a fixed library of course materials, and a system designed to support the specific strategy and materials.

A regular classroom relies more on implicit criteria for its definition: there is an instructor and, most likely, a required textbook. What takes place in a classroom (whether primarily lectures or discussions or reviews of assignments) and how an instructor chooses to teach his students may be difficult to capture in an evaluation. But we can assume such classroom practices remain fairly constant. Together regular classes closely resemble the practices that were followed in the previous semester and those that will continue in the next semester, and perhaps even those at another institution. Thus, we assumed that T and C represented well-defined conditions but also undertook observations to identify exceptions.

We expect an effect, if it occurs, to be evident from an outcome measure dependent on the treatments. Such a dependent variable (Y) might be a measure of course completion, student achievement, or student attitudes. There is further a definite time interval of students' exposure to an instructional condition: it starts at time t_1 and ends at t_2. For course completion the natural time frame would be the academic term. So students would register for a course under the T or C condition at t_1 and we would observe Y, completion status, at t_2. We may wish to impose a fixed time constraint on achievement and attitudes as well as completion. But such a rigid interpretation of exposure defeats the purpose of the TICCIT program and, in effect, forces an individualized curriculum back into a lock step pattern with an academic calendar. Instead, whenever a student completed his studies on the TICCIT system was the time at which we observed the value of Y for his course achievement or attitudes. There was an exception to this rule: we examined effects within a fixed time period for the math courses at one college. But this exception was a matter of necessity (see Chapter 3: Implementation of the TICCIT Program) rather than preference.

Estimating TICCIT's effects would be a simple matter if each student went through both the T and C conditions from t_1 to t_2. Then we could take the difference between his values for Y and state the effect. But it is impossible for each student to be in both conditions at one time. Although this sometimes happens in evaluation studies, it confounds rather than clarifies the effect. So we must settle on an approximation to having the same students under both conditions. The same students cannot take a course in two ways but similar students can.

Our estimates of program effects depend on comparisons between the values of Y for students in the T condition with values of Y for similar students in the C condition. Similarity here means that students were essentially identical on a set of variables measured at t_1. These variables, always measured before the onset of the T and C conditions or unchanged by the conditions (e.g., sex), are covariates. We denote the vector of all such covariates by X. Two students with identical values of X may be considered as similar as far as the relevant data set goes: these students are the same on every characteristic measured prior to the initiation of the treatment.

It might be helpful to enumerate the above assumptions before discussing the mathematical model based on them.

(1) There is a population (P) from which the students may be regarded as representative. Although the TICCIT demonstration took place at a community college, the evaluation actually dealt with several populations. Those students who enrolled for a target course defined a population. Further, most of the analyses for student achievement and attitudes necessarily dealt with the population which enrolled for and completed a course.

(2) There is a definite treatment condition (T) as well as a well-defined control condition (C). For this project these conditions were the TICCIT program and the regular classroom. An additional condition, programmed instruction, was available as a second control condition for one math course. Each student was in one of these conditions.

(3) There is a dependent variable (Y) which functions as a measure of the programs' effects. Our outcome measures covered course completion, student achievement, and student attitudes. Each was observed sometime after the initiation of the T and C conditions. The usual period of student exposure to a condition was the academic term.

(4) There is a vector of covariates (X) that determines the similarity of the student groups exposed to the different treatments. Whenever possible, assignment to an instructional condition was random or blind. However, students also took pretests and provided us with information on such background characteristics as age, sex, and grade point average. These variables observed prior to the onset of the instructional conditions served as our covariates.

2.4.b Mathematical Model

The dependent variable Y and the vector of covariates X may be regarded as having a joint distribution over the population P. This distribution depends on whether the students represent the population as exposed to the T or C condition. Thus, conditional on X, Y has a distribution dependent on which condition the student is in. Or, simply, the outcome for similar students is a function of the mode of instruction followed in a student's class. The average value of Y for students from P with covariate values X = x and who receive the treatment T is expressed as

$$\mu_T(x) = E_P\ (Y | X = x,\ T).$$

Similarly, the average value of Y for students from P who receive the control condition C is denoted by

$$\mu_C(x) = E_P\ (Y | X = x,\ C).$$

The functions $\mu_T(x)$ and $\mu_C(x)$, sometimes called response functions, represent the average value of Y in the two conditions for students from P with identical covariate values x. This is just a formal way to say that the outcome, whether course completion, achievement or attitudes, depends on the instructional condition (T or C) once we control for other variables (X) thought to influence that outcome (e.g., pretest score).

It follows, then, that the difference between these two functions is the treatment effect.

$\tau(x) = \mu_T(x) - \mu_C(x)$

This is the average difference in the value of Y for students whom we regard as identical since their covariate values equal x. The new function $\tau(x)$ is the effect at x: it represents the difference in anticipated program results for similar students. If $\tau(x)$ is averaged over the population P we obtain the treatment effect in the population. This is given as

$\tau_P = E_P\,[\tau(x)]$.

The purpose of our analysis is to estimate the treatment effect τ_P for each dependent variable Y and on the population P affected by the treatment. Our estimate of τ_P will be denoted by $\hat{\tau}_P$. If we further use $\sigma_{\hat{\tau}_P}$ to represent the standard error of the average effect, then $\hat{\sigma}_{\hat{\tau}_P}$ denotes the estimated standard error for the distribution τ_P. This report gives both the value of $\hat{\tau}_P$ and $\hat{\sigma}_{\hat{\tau}_P}$.

2.4.c Parameter Estimation

The analysis consists of three stages of parameter estimation. In the first we estimate the response functions $\mu_T(x)$ and $\mu_C(x)$. Next we can use these forms to arrive at the treatment effect at x, $\hat{\tau}(x)$, and average these to get the overall treatment effect $\hat{\tau}_P$. Then we need $\hat{\sigma}_{\hat{\tau}_P}$ to test the statistical significance of the effect. In order to estimate τ_P we must start with $\mu_T(x)$ and $\mu_C(x)$. We must decide on a form for these response functions in each population. This involves exploring a number of possible forms. It is not necessary that the two functions be linear or parallel. Of course should the data support such simplifications, we take advantage of them. Our primary objective is a powerful rather than a simple form. We want response functions which account for as much of the variance in Y as possible given the available data. As the explanation of Y variance improves, the accuracy of the response functions $\mu_T(x)$ and $\mu_C(x)$ also improves. With better accuracy in expressing the average value of Y we also get fewer alternative explanations for the difference $\tau(x)$ and such a difference becomes increasingly attributable to a true treatment effect. When response functions leave much of the Y variance unexplained, the difference $\tau(x)$ contributes little and τ_P can degenerate into a simple comparison of the mean values for Y by treatment. When response functions explain most of the variance in Y, then even a relatively small treatment effect can be detected and reported with confidence. So this phase of estimating τ_P is important though exploratory. We seek to reexpress variables (e.g., x^2 or log x rather than x), identify outliers (e.g., isolate the class given only half as much time as others for completing the posttest), and generally bring tools from exploratory data analysis to bear on the problem of simplifying and estimating the value of Y within the T and C conditions.

Estimating response functions can benefit from pooling data across groups within each population. For example, if we pool data from day classes and evening classes the size of our data base increases. Similar increments can result from pooling across academic terms or even across the T and C conditions. The only firm rule here is that we only pool across groups by assuming some version of parallel response functions in the groups. Naturally we cannot aggregate dissimilar data as we would if we tried to pool those populations enrolled in different courses. Instead we can consider each course as a distinct population and therefore a replication trial. The reason for pooling is to increase the relative sample size, and thereby improve our estimate of τ_P.

The estimated response functions $\hat{\mu}_T(x)$ and $\hat{\mu}_C(x)$ determine the treatment effect at x:

$$\hat{\tau}(x) = \hat{\mu}_T(x) - \hat{\mu}_C(x)$$

This is our best estimate of the relative increase (or decrease) in Y due to T for students with covariate values of x. Now we can use the data to arrive at an estimate of the overall effect τ_P.

In the simplest case we compute $\hat{\tau}(x_i)$ for every observation i in the study and average these student effects. But where we lack complete data (e.g., unobserved posttest performance under one condition due to a different course completion rate), we can only estimate τ_P averaged over those cases for which X equals x under both conditions. The unmatched observations still contribute to the previous phase in which we use all available data to estimate the form of the response functions. However, the estimated treatment effect τ_P exists only where X equals x under T and C.

We can define the anticipated difference between program outcomes as

$$\hat{\tau}_P = \frac{1}{n}\sum_{i=1}^{n} \hat{\tau}(x_i) = \frac{1}{n}\sum_{i=1}^{n} \left[\hat{\mu}_T(x_i) - \hat{\mu}_C(x_i)\right]$$

under T and C for n students. Often the size of the data set, n, is less than the total enrollment for a course, N. There will be students who fail to take the pretest. Others will not complete their studies and thus the value of Y for achievement or attitudes will not be observed. Consider the analysis for student achievement. The estimated treatment effect has meaning only for those students who complete a course and not for all who enroll. Should there be a vastly different completion rate in one condition than in the other (but still with parallel response functions), the achievement effect actually occurs for a limited number of cases in which X equals x under both conditions. Even worse cases can arise: there may be a treatment effect dependent on the value of X. If this happens for Y, the differential effect itself constitutes the major finding since other comparisons of program outcomes may subsume bias. These restrictions on the interpretation of treatment effects should be kept in mind as cautions against overly broad judgments of results. Our average treatment effect applies to n students out of a course enrollment of N. As n approaches N, we can be confident that the treatment effect, whatever it might be, applies to the entire population of students in a course.

How do we know whether a treatment effect once estimated constitutes a difference of statistical significance? We estimate the standard error of the average effect $\sigma_{\hat{\tau}_P}$. Since the response functions $\hat{\mu}_T(x)$ and $\hat{\mu}_C(x)$ themselves correspond to estimates derived from regression analysis, the estimated error $\hat{\sigma}_{\hat{\tau}_P}$ comes from values already available. We compute it from the standard error of estimate made in fitting a form to Y, the number of covariate values that go into each response function, and the number of observations averaged for $\hat{\tau}_P$. The computation of $\hat{\sigma}_{\hat{\tau}_P}$ can also depend on the functional forms of $\hat{\mu}_T(x)$ and $\hat{\mu}_C(x)$ and the placement of covariate values. In such cases we also need the covariance matrix for response functions but computation remains a technical detail.

2.4.d Application

Certainly there must be specific values associated with the vector of covariates X in order to estimate parameters and thereby determine the extent and significance of the treatment effect. It should be clear first that the covariates pertain to some dependent variable Y as well as a specific population

P. What follows is a brief discussion of Y, P and X, as well as their roles in parameter estimation.

The major dependent variables in this study will be course completion, student achievement, and student attitudes. Course completion is a simple dichotomous variable: Y_i has a value of 1 if student i receives college credit for his course work and 0 if he does not. Where the dependent variable is achievement, Y_i is the number of posttest items to which student i gave correct answers. Actually this may just reflect those items on objectives common across conditions for math courses, or simply a score on a four-point scale that instructors assigned to essays written as English posttests. An attitude score as the dependent variable represents the extent of a student's favorable reaction to his course. It is the sum of a student's responses to approximately twenty statements, with each response on a five-point scale of agreement.

The populations essentially correspond to the eight courses (see Figure 2.4) for which the TICCIT program was a curricular alternative to regular classes. Our evaluation deals with program results for each of the eight courses in at least two and, in most cases, three academic terms. Together with the preliminary trials of the implementation period for the TICCIT project, we can track results across as many as six terms. The product of the number of courses and number of terms gives the number of populations at one extreme. But the demonstration really involves only eight populations if we view the separate terms as replication trials. At another extreme would be one population if we accepted the TICCIT program as a general curricular strategy independent of college, course, and term. Our course-specific measures of achievement results preclude such an extreme position. We will conduct our analyses by course and term, and collapse across terms to attain larger sample sizes. Of course the population also depends on the nature of the dependent variable: achievement and attitude results generally pertain to those students who complete a course and not who enroll. So there will be subpopulations in each of the eight courses defined by the dependent variables.

The covariates in our analyses fall into three categories. The first and most important is the pretest. It serves as a measure of student ability and preparation prior to the start of a course and usually accounts for a good deal of the variation in posttest performance. For math we will use one such pretest per course, while for composition courses we take both an essay and an objective test as entrance measures. We will still refer to only one pretest score, S, for each student although two enter into the response functions for composition courses.

A second category of covariates relates to the demographic characteristics of the student. Some of these characteristics will be simple dichotomous indicators while others will be on a continuum. Sex, student status, and enrollment history exemplify traits for which an indicator with values of 1 or 0 suffices. A value of 1 might represent male, full-time student, or a repeat enrollment for a specific course, and a value of 0 female, part-time student, or first course enrollment. We need one dichotomous variable for each of these traits. Generally, R will stand for the vector of j such covariates where each student has supplied values for all j characteristics. Demographic variables on a continuum might be age, number of college credits, college grade point average, high school grade point average, and other characteristics on an interval scale. We will denote the collection of these k characteristics by the covariate vector

Q. Again, there must be observations on all k such variables for each student in order for them to be useful in estimating response functions.

Another class of covariates applies to groups of students rather than each individual. These categorical variables merely distinguish between types of sections, for example those in the college's day division and those in the evening, or those meeting three periods per week and those meeting five periods for the same course. In analyses across academic terms there would be a group variable for classes that met in the fall term as contrasted to those in the spring. These variables permit contrasts to be made among natural subpopulations. Where no evidence suggests a treatment effect dependent on such groups, we can pool data across these subpopulations. Otherwise we must estimate the differential treatment effects for the specific subpopulations. Whether we proceed to estimate one or several treatment effects depends on the form of the response functions established in the first, exploratory stage of parameter estimation. We will use the covariate vector M to represent the h group variables. Like the vector R for dichotomous student characteristics, variables indicated through M usually assume one of only two values (e.g., 1 for day and 0 for evening). Unlike either R or Q, two students in the same class must have identical M values since it is a group, not an individual, vector. It might be considered as a shorthand notation for blocking factors or grouping contrasts.

There is a fourth category of covariates that does not enter into all analyses: variables that indicate instructors. Indicator variables for instructor appear only in the English courses. The TICCIT program for math is independent of instructors to the extent that one college had no course sections as such and instead let students choose their own time schedule on the computer system and instructors rotate their time schedule as resource teachers. The design of the TICCIT program did call for a stand-alone approach to computer-assisted instruction. But one college decided to use the program as an adjunctive resource in its composition course. We report this fact now because it bears on the analysis strategy and defer further explanation until the next chapter. An instructor might teach under only the T condition or only the C condition, or both the T and C conditions. It is when an instructor teaches both ways that we can estimate dependence of the response functions on that instructor. Otherwise the variation in Y that might be attributed to instructor is confounded with treatment. Let I denote this vector of g instructors, then

$$I_g(i) = \begin{cases} 1 \text{ if student } i \text{ has instructor } g \\ 0 \text{ otherwise} \end{cases}$$

This vector serves a purpose similar to that of the group vector. It blocks student data according to instructor.

For a given population P there is now covariate information about

S pretest score
R demographic characteristics on a nominal scale (j variables)
Q demographic characteristics on an interval scale (k variables)
M group factors (h variables)
I instructor indicators (g variables)

and the response functions may be restated as

$$\mu_T\ (S,\ \{R_j\},\ \{Q_k\},\ \{M_h\},\ \{I_g\}) \text{ and}$$

$$\mu_C\ (S,\ \{R_j\},\ \{Q_k\},\ \{M_h\},\ \{I_g\})$$

where I_g only enters into the English analysis. The regression analogues to simplified response functions would take the form:

$$\mu_T(X) = b_0 + b_1\ (S) + \sum_j c_j\ R_j + \sum_k d_k\ Q_k + \sum_h e_h\ M_h + \sum_g f_g\ I_g + u$$

$$\mu_C(X) = b_0 + b_1\ (S) + \sum_j c_j\ R_j + \sum_k d_k\ Q_k + \sum_h e_h\ M_h + \sum_g f_g\ I_g$$

These simplified forms assume that the slopes on S are identical across groups and conditions. This is a testable hypothesis through interactions of S with M and T or C. Where exploratory analysis for the response functions contradict the hypothesis of identical slopes, we will examine more complicated forms of the response functions.

We actually estimate response functions in regressions of the dependent variable Y on the independent covariates S, $\{R_j\}$, $\{Q_k\}$, $\{M_h\}$, and $\{I_g\}$ with one additional variable TICCIT, where

$$\text{TICCIT}_i = \begin{cases} 1 \text{ if student } i \text{ is in T} \\ 0 \text{ if student } i \text{ is in C.} \end{cases}$$

If exploratory analysis justifies the simple model, then the estimated treatment effect $\hat{\tau}_P$ is simply $\hat{u}$. The regression reports its value as the coefficient for our variable TICCIT, and its standard error $\hat{\sigma}_{\hat{\tau}_P}$ follows from the standard error for the regression weight on TICCIT. Where it becomes necessary to reject the simplified regression model due to interactions, there will be an explanation of the form found for the response functions. It may be a substantive reason that has policy implications for the program or, more likely, an effect of maturation or another internal source of invalidity.

Of course not all our analyses follow these procedures for data analysis. We do adhere to the procedures as much as possible in studying course completion, student achievement, and student attitudes. But for student activities and faculty acceptance the analyses tend to be descriptive rather than inferential. And some cases will arise where the number of covariates exceeds the size of the subpopulation involved in a specific response function. Reason, too, plays a role in data analysis, as does knowledge of the variables and conditions. Perhaps the context in which the evaluation occurs, though, exerts a stronger influence on results than any of our careful plans, preparation of instruments, data collection, or data analysis.

Chapter 3

Implementation of the TICCIT Program

Regardless of results the introduction of an innovative curriculum into schools is in itself an achievement. This is especially true when the curriculum involves an application of instructional technology with the stated objective of supplanting traditional methods of instruction entirely. Cooperative and receptive schools need to be enlisted as demonstration sites for the curriculum program. And the particular schools may affect the extent to which an evaluation's results depict fairly what may be expected to happen elsewhere with other students or under different conditions. There must also be mechanisms for maintaining the commitment and involvement of selected schools as well as for preparing these demonstration sites for the use of the curriculum program. If evaluation results do reflect the real impact of the curriculum, there is also reason to consider its design and development as they might bear on other projects. These processes of selecting demonstration sites, preparing schools for the adoption of the curriculum, and developing the actual curriculum materials represent components of the whole implementation process.

This chapter addresses the implementation of the TICCIT program. Unlike subsequent chapters dealing with program outcomes, the focus here is on the processes involved in introducing the TICCIT program to community colleges and in developing courseware. The first section presents the rationale behind the choice of community colleges as demonstration sites and the factors taken into consideration in the selection of particular colleges as participants in the project. It also describes the students enrolled at these colleges and the courses offered on the TICCIT system.

The second section covers those aspects of project administration expressly concerned with facilitating the implementation of the TICCIT program, and recounts the colleges' staffing of the TICCIT program. Finally there is an overview of the design and production of TICCIT courseware.

3.1 Demonstration Sites

The demonstration of the TICCIT computer-assisted instructional system took place in community colleges. The particular community colleges chosen as demonstration sites, their respective student populations and the specific courses offered under the TICCIT program, undoubtedly played a major role in determining the results reported in this evaluation study. Also, any generalizations based on the evaluation must take into consideration the extent to which the characteristics of these particular community colleges conform with or depart from the characteristics of other possible sites. Both for appreciating the results attained in the TICCIT project and for making inferences about probable outcomes in other situations, it may be helpful to examine the context of the evaluation.

The decision to enlist community colleges as participants in the demonstration was a careful and planned choice consistent with the project's goals. The developers of the TICCIT program sought to create a market success for computer-assisted instruction, and community colleges represented a market with the potential for high volume and low resistance. Among all sectors of education, community colleges had shown the most dramatic upsurge in enrollment. Their total student enrollment had increased three-fold between 1960 and 1970, and it was expected to double within another decade. Furthermore, there was a concentration of this total enrollment in certain courses, notably introductory courses in English and mathematics. If students took just one such course per academic term and if computers could support full courses in these disciplines, the TICCIT program might assume 20% of the instructional load at community colleges. It seemed clear that community colleges presented a viable market from the standpoint of volume.

Estimates of instructional costs also contributed to the selection of community colleges for demonstrating the TICCIT program. Its developers believed that the costs of the TICCIT system would be within reach for community colleges with a minimum enrollment of 800 students. Forecasts indicated that nearly three-fourths of all community colleges would be that large by 1981. These projections assumed that the TICCIT program would support about 20% of all student contact hours at a college and thus justify its purchase cost to the college. The developers found further support for the financial feasibility of the project in the space and faculty demands of traditional instruction. A survey conducted in 1968-69 revealed that community colleges devoted 18 square feet of classroom space per student, whereas the individual carrel space required for the TICCIT project would be only 12 square feet per student. Despite their rapid growth in enrollment, the student-faculty ratio at community colleges had fallen from 25.77 to 1 in 1960-61 to 20.03 to 1 in 1969-70. This fact coupled with a steady increase in average faculty salary meant that the costs of traditional instruction would continue to rise. The TICCIT program was to permit much higher student-faculty ratios through its mainline instruction, and higher ratios implied greater cost-effectiveness.

Although educational institutions may tend to be conservative and somewhat resistant to change, community colleges were thought to be receptive to innovations such as computer-assisted instruction. A number of colleges had already adopted learning systems geared toward the individual student. Community colleges generally had a policy of open enrollment and, hence, a sizeable percentage of students weak in basic skills. This made individualized instructional systems particularly attractive for community colleges. Indeed, many state codes for the construction of new junior colleges recommended learning resource centers with individual carrels rather than the physical layout of traditional libraries. It also seemed that administrators at community colleges retained substantial authority for making decisions and commitments. Such central responsibility suggested the feasibility of reaching timely agreements with selected demonstration sites and maintaining channels for smooth communication. For their growth and potential market size, their potential for a cost-effective application of computer-assisted instruction, and their apparent receptivity to innovative instructional systems, the developers of the TICCIT program chose community colleges as appropriate demonstration sites.

3.1.a Site Selection

The selection of specific community colleges to participate in the demonstration took place in the 1971-72 academic year. Geographical proximity to the developers was a key factor in the selection process. Project resources and time schedules did not permit an open search for participants. Instead the developers sought one site close to the location of system design and another site close to the center for courseware production. Although demonstration sites located close to the developers could come to depend heavily on external support, the wide geographical separation of system design and courseware production meant that one site would still be quite distant from the system engineers and another far from the courseware specialists. Actually, it became necessary for representatives of both courseware production and system design to spend extended periods of time at the colleges. The installation of TICCIT systems and the refinement of courseware required heavy external support. Such dependence on developers should perhaps be expected for the initial implementation of a major instructional program. Criteria beyond geographical proximity further narrowed the candidates for participation. College facilities had to accommodate the physical space needed for the TICCIT hardware and terminals. Support staff, such as computer operators and student proctors, had to be available at the colleges. Enrollment had to be high enough to justify a full TICCIT system with 128 terminals, in anticipation of sufficient student use to achieve cost-effectiveness. And there had to be substantial overlap between the college's curriculum structure and the courseware planned for the TICCIT project.

According to these criteria it was possible to identify several eligible participants. Selection among these eligible participants then focused on their student enrollment in courses covered by the TICCIT program and their student profile in comparison with national norms for community colleges. The two colleges with the highest enrollment in target courses and the greatest similarity to national norms received, and accepted, invitations to participate in the project. They were the Alexandria Campus of Northern Virginia Community College and Phoenix College of the Maricopa County Community College District. Both Northern Virginia Community College and Maricopa County Community College District had several community college campuses tied together under a single administrative board. These systems had been approached initially due to their proximity to either the MITRE Corporation in McLean, Virginia or Brigham Young University in Provo, Utah. The criteria for facilities, support, enrollment, curriculum and representativeness guided the final selection of the Alexandria and Phoenix campuses.

Agreements between the developers and the colleges stipulated the responsibilities of each participant. The MITRE Corporation would install a TICCIT system at each demonstration site during the summer of 1974, and it would provide courseware equivalent to two mathematics courses and two English courses. The developers also promised to train teachers and deliver manuals for the use of the TICCIT system. In return, the colleges would support the installation and operation of the system. Their specific responsibilities included facility modifications, carrel construction, utilities, air conditioning, and support personnel (technicians, proctors, instructors, and a local project director). It was also agreed that each demonstration site would cooperate with an independent agency in the conduct of a formal evaluation. Finally, the agreements called for establishing a committee with the expressed purpose of coordination among participants in the project. That committee included representatives of the developers, demonstration sites and the evaluator. Its meetings would serve as an impetus for reviewing the project′s status and for taking action to resolve any unanticipated problems.

The process of selecting demonstration sites for the TICCIT project had been planned and carried out in an exemplary manner. It succeeded in enlisting the cooperation of two community colleges which met the criteria for selection. The extent of their commitment to the project became evident later as the colleges worked together with the developers toward the completion of the TICCIT program. The developers' foresight in inviting the evaluator to participate in site selection and in making cooperation with the evaluator part of the agreements reached with the colleges also established the evaluation as an important component of the project. This early recognition of the evaluation's importance set the foundation for the colleges' cooperation in all phases of this study.

3.1.b Student Profile

Each of the community colleges chosen to be participants in the project had a high student enrollment. This was a prerequisite to participation since the number of students in just a few selected courses had to justify the use of a full TICCIT system with 128 terminals. At the start of the demonstration in the 1975-76 academic year, the Alexandria Campus of Northern Virginia Community College had an enrollment of over 9,000 students and Phoenix College of the Maricopa County Community College District had nearly 14,000 students in attendance. Because the characteristics of these student populations may determine whether generalizations to other contexts would be appropriate, a brief profile of the students at each college appears in Table 3.1.

Consistent with the nature of the student population at most community colleges, the typical student at Alexandria and Phoenix was registered on a

Student Profile

Fall Academic Term, 1975-76

Alexandria Campus	N	%	Phoenix College	N	%
Total Student Enrollment	9319	100.0	Total Student Enrollment	13990	100.0
Curriculum Level			**Curriculum Level**		
Freshman	1243	13.3	Freshman	10542	75.4
Sophomore	643	6.9	Sophomore	3448	24.6
Unclassified	7433	79.8			
Full-time	2342	25.1	Full-time (>12 hrs.)	4314	30.8
Part-time	6977	74.9	Part-time (<12 hrs.)	9676	69.2
Sex			**Sex**		
Male	4499	48.3	Male	7571	54.1
Female	4820	51.7	Female	6419	45.9
Age			**Age**		
17	123	1.3	15-19	2903	20.8
18-21	2271	24.8	20-25	4116	29.4
22-24	1567	17.0	26-35	4661	33.3
25-34	3624	39.3	36-45	1416	10.1
35-44	932	10.1	46-55	615	4.4
45-54	481	5.2	55-	221	1.6
55-64	175	1.9	Unknown	58	.4
65-	42	.4			
Ethnic Background			**Ethnic Background**		
American Indian	27	.3	American Indian	214	1.5
Black	1169	12.5	Black	500	3.6
Oriental	219	2.4	Oriental	87	.6
Spanish surnamed	173	1.9	Mexican-American	1377	9.8
Caucasian	7471	80.2	Other	11812	84.4
Other	260	2.8			
Marital Status			**Marital Status**		
Single	5225	56.4	Single	7258	51.9
Married	3650	39.4	Married	5784	41.3
Unknown	394	4.3	Unknown	948	6.8
Residence			**Residence**		
State	7810	83.8	County	13192	94.3
Other	1509	16.2	State (not county)	81	.6
			Out-of-state	612	4.4
			Foreign	105	.8

Table 3.1

part-time basis. Less than one-third of the students had enrolled for a full complement of courses. The large percentage of unclassified students at Alexandria (79.8%) reflects the role of the college in serving the interests of the community. Students often registered for particular courses without any definite plans for completing a two-year curriculum of studies. Phoenix College considered such students to be freshmen. Its higher proportion of students at the sophomore level (24.6%) perhaps attests to its academic history and reputation: Phoenix College had been established in 1920. Northern Virginia Community College came about as a result of legislation passed in 1964, and its Alexandria Campus moved into permanent facilities for the 1973-74 academic year. Thus, Alexandria was a much younger college and had fewer students committed to the pursuit of a formal degree.

Both colleges attracted students of a wide range of ages. Most students were between 25 and 35 years of age. The student populations also tended to reflect the ethnic background of the surrounding community. Black students constituted the largest minority attending Alexandria while Mexican-Americans were the largest minority enrolled at Phoenix. About two-fifths of the students were married, and the majority of the students held jobs (see Appendix L). Alexandria, as might be expected from its location in the Washington, DC metropolitan area, drew a larger percentage of students from other states of residence than did Phoenix. Phoenix drew heavily from its home county Further information about those students in courses offered on the TICCIT system can be found in Appendix K, which lists their reasons for electing a particular section, and Appendix L, which includes additional demographic characteristics. On the whole, the two community colleges selected as demonstration sites appear to be similar to most other community colleges of comparable size.

3.1.c Target Courses

The selection of courses to be implemented on the TICCIT system was as careful and deliberate as the selection of demonstration sites. Opportunity had been a major consideration in determining appropriate target courses. Its developers wanted the TICCIT program to be cost-effective, and this meant distributing the costs of the computer system among a large number of students while keeping the expenses of curriculum development to a minimum. The large numbers of students enrolled for just a few courses in introductory algebra and basic English implied that the opportunity for achieving a cost-effective balance existed at community colleges. Enrollment figures for remedial courses in mathematics and English could also be taken as evidence of a need for an innovative approach to instruction. The TICCIT program offered content coverage parallel to those community college courses in greatest demand, and it provided an instructional system for promoting mastery among individual students.

Actually the mathematics curriculum available on the TICCIT system (see Appendix A) corresponds to a sequence of three separate algebra courses, and the English courseware (see Appendix B) is roughly equivalent to one course in fundamentals of the English language and another in composition. Thus, a student enrolled for four semesters of academic study might take one course per term on the TICCIT system. Through a limited number of carefully chosen courses the TICCIT program could support as much as one-fifth of the courses taken by a community college student. But the colleges first had to approve courses taken on the TICCIT system as fully acceptable alternatives to courses taught in a conventional manner.

The colleges themselves decided which mathematics and English courses might best fit the curriculum available on the TICCIT system. For this reason the content specifications of the courseware adhered closely to a traditional structure for subject matter. It was in delivery and design that the TICCIT program afforded leverage for instruction. Courseware coverage was intended to facilitate a smooth integration into the existing academic curriculum. The mathematics faculty at Phoenix College adapted the courseware to fit their most popular sequence of algebra courses while the mathematics department at the Alexandria Campus of NVCC concentrated on use of the TICCIT program for developmental courses in algebra. Conversely, members of the English department at Phoenix initially adopted the TICCIT program for support of their remedial course in English fundamentals while faculty at Alexandria applied the courseware for their course in composition.

Textbooks and Requirements. The four mathematics courses given on the TICCIT system at Phoenix College spanned a full sequence of algebra courses. Beginning Algebra covered rational expressions, linear equations and polynomial expressions with an introduction to sets. Students in sections of Beginning Algebra, listed as Math 007 throughout this report, had to complete units 22, 21, 20 and 17 on the TICCIT system in order to receive credit for the course. Students in lecture sections followed Keedy and Bettinger's Introductory Algebra. It was expected that students in lecture sections would meet for three class periods each week for the duration of the semester and would receive homework assignments. It was recommended that students in TICCIT classes schedule six hours per week on the computer system and continue attending these classes until they completed the TICCIT units necessary for course credit. All students enrolled for Math 007 took the same final examination, which was also the posttest for the evaluation.

Two other courses represented the continuation of the algebra sequence at Phoenix. Intermediate Algebra and College Algebra, Math 106 and Math 117 respectively, also carried three credits and met for three classroom sessions per week in the lecture format. Their content coverage, in terms of the textbooks required in regular classes and the courseware units required in TICCIT sections, is given in Table 3.2. The fourth math course offered on the TICCIT system was really a combination of Beginning Algebra and Intermediate Algebra. Called Fundamentals of Algebra, it met for five classroom periods per week as a lecture class and carried five credits. There was a common final examination, which also served as the posttest for the evaluation, for all sections of each of these algebra courses (see Appendix C).

At Alexandria the two mathematics courses offered on the TICCIT system were part of a developmental math sequence. Their credits could not be applied toward transfer to a four-year college. Both Algebra I and Algebra II had five class sessions per week throughout the quarter. Students who registered for lecture sections, programmed instruction, or TICCIT classes, had to attend classes for five periods per week. Rather than a point scale or usual letter grades, students completing all of the required course material received a "satisfactory" grade. Taking a posttest for the purposes of this evaluation was also made a prerequisite to successful completion of the courses. The textbooks adopted for Algebra I and Algebra II were Russell and Collins' Elementary Algebra and Russell and Lanning's Intermediate Algebra, respectively. The courseware units required in TICCIT classes appear in Table 3.2 (see also Figure 1.3 and Appendix A for unit contents).

The course in English fundamentals given at Phoenix was intended for students who needed remedial instruction prior to enrolling in a composition course. English 19 and English 29 provided a review of basic skills and concentrated particularly on sentence and paragraph structure. Essentially the two courses were parallel in emphasis and coverage and just had different designations in the day and evening divisions of the college. Both met for three class periods per week throughout the semester. Instructors for lecture-discussion sections tended to use the same textbooks in the day and evening divisions, and students in TICCIT classes had to complete the same map of courseware units. That map closely followed the suggested courseware structure (shown in Figure 1.4) except that it omitted units pertinent to organizing and writing essays (units 9 and 1).

The faculty of the English department at Alexandria chose to use the TICCIT system in an adjunctive manner for their course in composition. Rather than the usual three classroom sessions per week, students in TICCIT classes went to work on the computer system for those sessions specified by their instructor. The student time spent on the TICCIT system was in place of regular classroom periods. Which courseware units a student had to study depended both on the class assignments made by a particular instructor

College	Academic Term	Course	Number of Credits	Number of Class Periods	Textbooks	TICCIT Courseware
Alexandria	Quarter	Math 31 Algebra I	5 (non-transfer)	5 per week	Russell & Collins *Elementary Algebra*	Units 22, 21, 20, 19 18, 17, 16
		Math 32 Algebra II	5 (non-transfer)	5 per week	Russell & Lanning *Intermediate Algebra*	Units 15, 14, 11, 10, 9, 8, 7
	(1975-76)	English 111 English Composition I	3	3 per week	McCrimmon *Writing with a Purpose*	Units 11, 10, 9 and others
	(1976-77)	English 111 English Composition I	3	5 per week (with laboratory)	Baker *The Complete Stylist*	Units 13, 12, 8, 7, 5, 4, 3
Phoenix	Semester	Math 007 Beginning Algebra	3	3 per week	Keedy & Bettinger *Introductory Algebra*	Units 22, 21, 20, 17 (one lesson per week)
		Math 106 Intermediate Algebra	3	3 per week	Wooton & Drooyan Intermediate Algebra	Units 19, 18, 16, 15, 14 (one lesson per week)
		Math 108 Fundamentals of Algebra	5	5 per week	Wooton & Drooyan *Intermediate Algebra*	Units 22, 21, 20, 19, 18, 17, 16, 15, 14
		Math 117 College Algebra	3	3 per week	Leithold *College Algebra*	Units 13, 11, 10, 9, 8, 7, 2, 1
		English 19 and English 29 Basic English	3 (non-transfer)	3 per week	Gallo-Rink *Shaping College Writing* Blumenthal *English 3200* Adams *Think, Read, React, Plan, Write, Rewrite* Ellsworth *English Simplified*	Units 13-10, 8-2

Target Courses

Table 3.2

and on the performance of the individual student. Since the course was in composition, most instructors assigned the units on writing (units 11, 10 and 9) as course requirements and supplemented these with units on sentence structure (units 8 and 3) for certain students. The emphasis on writing was apparent in every section, regardless of the mode of instruction, by the number of themes which students had to submit. Often there were assignments on six topics: description; narration; example and illustration; comparison and contrast; cause and effect; and analysis. The primary textbook for English 111 in the 1975-76 academic year was McCrimmon's Writing with a purpose with supplementary use of Decker's Patterns of exposition.

In the fall quarter of the 1976-77 academic year the emphasis shifted to the use of the TICCIT system in laboratory sections of English 111. These sections met for five periods per week but still carried three course credits. The additional periods provided students weak in their command of English fundamentals with an opportunity for review. Most classes on the TICCIT system spent time studying those units on grammar and the mechanics of writing. Instructors generally thought this to be an appropriate application of the TICCIT program as it allowed them to focus their classroom sessions on actual writing. Other sections of English 111, those in a lecture-discussion format, followed Baker's The complete stylist.

Enrollment in Target Courses. Students had to retain the prerogative to choose their own courses at registration. It was not appropriate to assign students randomly to the courses designated as target courses for the demonstration. But it was possible to implement different procedures for attaining equivalent comparison groups in the evaluation. In the first academic term of the demonstration period, students registering for algebra courses at one site received their section assignments, to either a lecture section or a TICCIT class, on a random basis. In other cases the college's course schedule listed available sections without identifying the instructional condition. Students then enrolled in a particular section while unaware of its status as a lecture discussion or TICCIT class. Later in the demonstration period it became necessary that course schedules specify the instructional condition for all sections of target courses. Often students unable to finish course requirements in one academic term wished to reenroll for the same course under the same condition in the next term. To do so the students needed to know whether a section was to be a regular lecture section or a section under the TICCIT program. These were the three principal methods followed in placing students fnto sections of target courses: random assignment; blind enrollment; and self-selection.

About one-third of the students enrolled for algebra courses in the fall semester at Phoenix College declined the random assignment given to them. They instead indicated a strong preference for a different instructional condition. Of those students who wanted a lecture section rather than a TICCIT class, the most common explanation was simply a preference for the traditional method. Students also cited friends' unfavorable reactions to the TICCIT program, insufficient knowledge of the program and the amount of time required on the computer system as reasons for declining an assignment to the TICCIT condition. Other students refused an assignment to a lecture section in order to take an algebra course on the TICCIT system. Their reasons for this preference were often the recommendations of friends, the self-paced instruction available through the TICCIT system, and the lure of an innovative approach to learning. No significant difference was found between those students who accepted their section assignment and those who expressed a strong preference for a different condition in terms of their entrance ability. And there was no significant difference between these two groups in terms of program outcomes.

At Alexandria students enrolled in target courses without specific knowledge of the instructional condition. The course schedule listed sections of algebra courses as either "lecture" or "programmed" just as the sections had been listed prior to the introduction of the TICCIT program. Since the use of the TICCIT system was supplementary for the course in English composition, the schedule did not distinguish sections of this course by condition. As shown in Appendix K, students chose to enroll in a particular section of a math course primarily because they wanted to take the course under the instructional condition listed for that section or because the section met at a convenient time. In the fall quarter of the 1975-76 academic year, most students in TICCIT classes had been unaware of their section's instructional condition. This changed as the demonstration progressed and students needed to know each section's condition in order to continue studies from one quarter to the next. It was clear that students registered for their English classes on the basis of the time of class sessions. Repeatedly students gave "class met at a convenient time" as their basis for enrolling in a particular section of the English composition course (see Appendix K). The students in TICCIT classes were generally quite similar to those in lecture-discussion sections. Appendix L contains profiles of these two groups on a number of characteristics. The only anomaly was a tendency for a greater percentage of the students in TICCIT classes to be employed full-time. Perhaps students with jobs believed that it would be easier to arrange a convenient schedule of classes on the TICCIT system.

A similar pattern of choices held when the college's course schedule identified sections by condition. In the spring semester at Phoenix College, students registered for certain sections of algebra courses according to the section's instructional condition and its hours for class sessions. Students registered for certain sections of the course in English fundamentals because the sections met at convenient times. However, over one-fourth of the students enrolled in TICCIT classes reported that they had chosen their course section because other sections were already full. This happened in the spring semester of the 1975-76 academic year in math courses and again in the next fall semester in English courses. Despite this apparent difference in students' reasons for enrolling in a particular section, there were just small differences in the profiles of students in TICCIT classes and students in lecture-discussion classes. The differences which did occur were insufficient to call the initial similarity of the groups into question, and none was significant.

Under all three procedures for assigning students to sections of target courses there was a remarkable consistency in why students chose particular classes. Given a choice of conditions students in math courses decided on a specific section by its manner of instruction and its class times. Students in English courses registered for a particular section primarily for the convenience of its schedule. And regardless of the procedure followed in forming TICCIT classes and lecture sections, the comparison groups seemed equivalent at the start of an academic term. Further details on students' reasons for enrolling in certain sections and on the composition of comparison groups appear in Appendix K and Appendix L. Table 3.3 gives an illustration of the kind of information found in these appendices; it presents data on student enrollment in target courses from a case in which students selected a course section according to its instructional condition.

3.2 Project Administration and Site Management

What promotes the transfer of an innovative curriculum program into schools? Certainly care in the initial selection of demonstration sites can facilitate the process of transfer. Schools able to accommodate the program and known to be receptive to its goals should provide fertile ground for a demonstration. But how do these schools come to participate in the project so that their administration and faculty will both support and accept the new instructional program as part of the school's curriculum? The developers of the TICCIT program took a systematic approach to the problems of implementation. They anticipated what issues might be involved in the introduction of the TICCIT program into community colleges, and they established formal mechanisms for dealing with these issues. Implementation became an explicit concern in the administration of the overall project.

3.2.a Mechanisms for Implementation

A capsule summary of the mechanisms established for facilitating implementation may be of greater import than an historical account of a

Reasons for Section Selection
Phoenix College
Math 007, 106, 108 and 117
Spring Semester, 1976

	TICCIT (N ≅ 309)		Lecture (N ≅ 553)	
	N	Percent	N	Percent
Knew about instructional method at registration	261	84.5	428	80.3
Section was recommended	126	40.8	111	20.8
By classmate	56	18.1	43	8.1
By instructor	46	14.9	30	5.6
By counselor	24	7.8	39	7.3
Reasons cited for section choice:				
To take a course with TICCIT				
Primary reason	100	32.4	1	0.2
Second most important factor	45	14.6	3	0.6
To get a programmed instruction section				
Primary reason	19	6.1	14	2.6
Second most important factor	26	8.4	8	1.5
Preference for lecture/discussion instruction				
Primary reason	5	1.6	201	37.7
Second most important factor	7	2.3	94	17.6
Class met at a convenient time				
Primary reason	63	20.4	146	27.4
Second most important factor	90	29.1	156	29.3
Other sections already full				
Primary reason	82	26.5	25	4.7
Second most important factor	21	6.8	23	4.3
To take course with a particular instructor				
Primary reason	8	2.6	56	10.5
Second most important factor	4	1.3	48	9.0
No particular reason				
Primary reason	14	4.5	58	10.9
Second most important factor	41	13.3	82	15.4

Enrollment in Target Courses

Table 3.3(a)

Student Demographic Profile
Phoenix College
Math 007, 106, 108, and 117
Spring Semester, 1976

	TICCIT (N ≅ 309)		Lecture (N ≅ 533)	
	Mean	sd	Mean	sd
Age (years)	23.12	6.5	24.23	6.7
College grade point average	2.94	.5	2.95	.6
Total college credits	27.70	27.8	26.81	23.7
High school grade point average	2.75	.6	2.74	.6
Sex:	N	Percent	N	Percent
Male	310	69.0	334	62.7
Female	139	31.0	194	36.4
High school curriculum:				
General	162	52.4	294	55.2
Vocational	7	2.3	17	3.2
College preparatory/academic	68	22.0	124	23.3
GED	34	11.0	57	10.7
Student load (credit hours for current term):				
Part-time	92	29.8	203	38.1
Full-time	201	65.0	324	60.8
Employment (current term):				
None	81	26.2	128	24.0
Part-time	109	35.3	163	30.6
Full-time	99	32.0	226	42.4
Previously enrolled in this course:				
Total	70	22.6	89	16.7
TICCIT	50	16.2	26	4.9
Lecture	9	2.9	49	9.2

Enrollment in Target Courses

Table 3.3(b)

project's life. Especially in the TICCIT project where the attention devoted to implementation was a formal part of project administration, it is easier to identify and relate the manner in which the developers dealt with issues such as maintaining communication among participants and preparing faculty for different duties under a new curriculum program. The highlights of the implementation process appear here not as milestones but as specific strategies adopted by the developers. These strategies illustrate both the range of problems which can arise in a major demonstration project and effective mechanisms for overcoming them. The TICCIT project did succeed in implementing an innovative curriculum program in schools and in completing a demonstration of that program's effectiveness.

College Liaison. A member of the developers' staff assumed responsibility for liaison with the community colleges, and this came before the final selection of demonstration sites. When two colleges joined the project as participants, there was already a central point of contact with the developers. Each college in turn designated one person from its faculty to serve as a local project director and to represent the college's interests in planning the project. This approach of appointing one specific person as a channel for all communications simplified exchanges among participants. Indeed, the developers' representative made regular contact with each of the other participants in the project throughout the early stages of the project. Even the evaluator received an informal status report through a semi-monthly telephone call from the developer. These contacts established a regular pattern of communication among participants.

Appointing a manager of implementation for the developers and local project directors for the colleges facilitated planning the demonstration and implementing the TICCIT program in community colleges. There was ready access to a person with the responsibility and authority to represent each participant in reaching decisions. It also became a simple matter to resolve ambiguities about the developers' plans or the colleges' procedures, and this avoided much confusion and doubt. Certainly the talents of the individuals chosen as representatives of their institutions helped to make smooth communication among participants a reality. But it was the anticipation of a need for regular contacts and the appointment of a manager and project directors that put a mechanism for communication into place.

Coordinating Committee. Agreements reached with the colleges as part of their formal commitment to the project stipulated that there would be a committee formed to coordinate all project activities. The committee included the persons designated as project directors for the developers, for the colleges and for the evaluator, as well as the presidents of the colleges and a senior vice-president for the developer. Its membership reflected the committee's level of responsibility in reviewing the progress of the project and taking immediate action in order to resolve any problems. Its purview took in the project's adherence to milestones, each participant's fulfillment of obligations, and the financial resources available to the project. The committee met twice in each year of the project.

Complications usually occur in a large developmental project under a tight schedule, and the TICCIT project was no exception. Frank discussions of problems and priorities within the coordinating committee helped to identify those issues which required immediate attention. The committee's members had sufficient authority to take action and make commitments for their institutions. It was possible to resolve conflicts before they seriously threatened the project's success in mounting a demonstration. This senior level committee was probably essential to the coordination of the project among participants.

Implementation Plan. Before community colleges entered into an agreement to join in the project as demonstration sites, the developers of the TICCIT program began to prepare an implementation plan. The purpose of the document was to provide participants with specific details concerning the preparation, installation and operation of TICCIT systems at community colleges. Drafting the implementation plan over one year in advance of the use of the TICCIT program in schools at least made participants sensitive to the scope of work entailed in the demonstration. And both the developers and the colleges began to consider ways to accomplish specific tasks well in advance of their schedule for completion. Table 3.4 lists the sections of the implementation plan and the participant responsible for each section.

Although the plans as set forth in the implementation document did not always provide the best match for later conditions, these plans did represent a sound basis for entering into the demonstration. The implementation plan had passed the approval of each participant and so provided written documentation on procedures and operations. If the developers and the colleges disagreed on a crucial point of the implementation plan, a final decision was left to the coordinating committee. Here was a reference and guide for the implementation process and the conduct of the demonstration.

That much of the implementation plan later became obsolete or inappropriate could be expected given the evolving nature of an ambitious project. At

Section	Topic	Responsible Party
A	Management and Organization	Developer
B	Schedule of Activities	Developer
C	Support Requirements	Community Colleges
D	Facility Preparation	Community Colleges
E	Training	Curriculum Developer and Community Colleges
F	Coordination (Courseware Development and Implementation)	Curriculum Developer
G	Curriculum Integration	Community Colleges
H	Installation and Checkout	Developer
I	Operations	Community Colleges
J	Contingencies	Community Colleges
K	System Maintenance	Developer
L	Formative Evaluation	Curriculum Developer
M	Summative Evaluation	Evaluator
N	Visitor Control	Community Colleges
O	Supporting Documentation	
P	Definitions	

Table 3.4

Contents of Implementation Plan

the outset of its preparation the developers thought it would be necessary to update and revise the plan. That the bulk of the document actually did reflect the steps taken in implementing the TICCIT program is a tribute to its usefulness.

Community College Authors. Four faculty members from the community colleges relocated to the site of courseware production for a period of six months. There was one representative from the mathematics department and another from the English department of each college. They had the familiarity with community college students and the knowledge of the colleges' curriculum structure which the developers themselves lacked. The developers understood this weakness and had invited faculty from the community colleges to spend the second half of the 1972-73 academic year with the courseware production teams. These community college authors played an important role in revising the initial content specifications for the TICCIT curriculum so that they would closely conform to the content of the target courses.

Besides contributing to the content specifications of the courseware, the community college authors made the TICCIT program a product of the developers and the colleges. There could have been greater faculty resistance to implementing a curriculum program from an outside source had not their colleagues helped to shape and define the program. And the involvement of community college authors set a precedent for later efforts. As the project came nearer to the demonstration phase with some tasks still incomplete, members of the mathematics and English departments of the community colleges devoted substantial time and effort to readying the curriculum for students. Enlisting community college authors was a major step toward gaining faculty acceptance of the TICCIT program and reaching a set of content specifications appropriate for the colleges.

Faculty Training Program. A summer program was offered to faculty members in order to prepare them for the use of the TICCIT system. The training program took place in the summer of 1974 just as the colleges started experimental classes based on the TICCIT curriculum. Eight faculty members, five math instructors and three English instructors, attended an intensive series of presentations at one of the community colleges. Three math instructors attended a parallel program given at another of the community colleges. The developers of the courseware conducted these sessions over a period of almost three weeks at each college; they also provided a manual with sections on an introduction to the TICCIT program, administrative procedures, handling student problems and authoring.

The sessions did familiarize faculty with the TICCIT system, particularly its design and its capabilities. But there was no opportunity to prepare instructors for their responsibilities in TICCIT classes. Neither the facilities nor the experience existed for such preparation. The computer system was not yet fully operational and much of the courseware remained unavailable at the community colleges. Moreover, there had not been a course under the TICCIT program given anywhere which could serve a model. Faculty had to learn about their new role as instructors in TICCIT classes as they began to use the TICCIT program in the pilot year, the 1974-75 academic year, of the project. Had there been both an initial orientation session to acquaint faculty fully with the TICCIT system and a later program to prepare instructors for their responsibilities in TICCIT classes, with this program offered after the experience of a modest field trial, it might have been easier for the developers to define the teacher's role under the TICCIT program and simpler for the faculty to learn about the computer system and the course materials as they worked at a terminal.

Student Handbook. The student handbook was intended to serve as a reference and guide for students enrolled in a mathematics or English course under the TICCIT program. It contained the same statements of objectives and subject matter rules that appeared on the TICCIT system. But the handbook had them in a written, bound form familiar to students. There were few examples and no practice problems in the handbook since its function was as a supplement to the courseware available on the computer system rather than as a textbook for student learning away from the system.

Few students actually purchased the handbook. If a student was alread on the TICCIT system, the handbook was redundant. If a student was at home the handbook could not serve as a sourcebook for studying examples or for working problems. To replace the handbook the colleges developed a set of basic instructions for student use of the TICCIT system. These instruction distributed to all students in a course under the TICCIT program, covered the mechanics of accessing courseware, course requirements, and standards for grading. They provided mechanical and administrative information which complemented the instructional material available on the TICCIT system.

3.2.b Staffing

The amount of staff necessary for the TICCIT program is a critica issue since a major goal of the project was to demonstrate a cost-effective application of computer-assisted instruction. In order to be cost-effectiv the TICCIT program would need to operate under a much higher student-faculty ratio than regular classes or result in substantial gains in outcomes such as course completion rates and student achievement. Seldom does a school define its student-teacher ratio in such a way as to include support staff such as counselors and librarians. This makes it difficult to compare the staff complement behind the TICCIT program with an equivalent for the traditional lecture-discussion mode of instruction. Here we cannot even offer a definition of the staff required for the TICCIT program. What follows is simply a description of the staffing adopted by the two community colleges in the demonstration.

Staff with responsbilities related to the TICCIT program fell into three categories: administrative, instructional and technical staff. The project director of each college was the administrative staff. This person reported to the college's president and collaborated closely with the developer and evaluator on all project activities. The responsibility for implementing the TICCIT program within the college rested with the project director, along with the budget and technical details of the program. Once the program had been implemented and the demonstration completed, the position of the college's project director became obsolete. Presumedly, the TICCIT program would then be well integrated with the college's operations and accepted as part of the curriculum structure, and there would no longer be need of a college project director.

Faculty members and proctors provided instructional support for students on the TICCIT system. Faculty maintained their affiliation with an academic department and taught TICCIT classes as part of their course load. In a sense there were no TICCIT teachers since no instructor taught only classes on the TICCIT system. Instead, members of the mathematics and English departments accepted assignments to TICCIT classes and received credit toward their full-time load of courses. The total number of load hours granted to instructors with assignments to TICCIT classes was the equivalent of about three full-time faculty positions at each college. This figure reflects assignments to both mathematics and English courses during the demonstration phase of the project.

A section of an English course given on the TICCIT system carried the same number of load hours and contained roughly the same number of students as any other section. Thus, five sections of a three-credit English course under the TICCIT program amounted to the equivalent of one full-time faculty position. The usual ratios of students to teachers and of faculty load hours to classroom contact hours held for those sections of English courses offered on the TICCIT system.

A math instructor received only three-fourths or four-fifths, depending on the college, of a faculty load hour for each contact hour spent with students on the TICCIT system. While a lecture section of Algebra I would yield five load hours, the same course taught under the TICCIT program would carry four load hours. This policy had been adopted by the colleges because math classes on the TICCIT system presumedly required no outside preparation of lectures or grading of homework assignments. Classes of Algebra I under a programmed instruction format also carried less than one load hour per contact hour. A full-time faculty position in mathematics usually entailed teaching five sections of a three-credit course; the equivalent of a full-time instructor could cover six sections under the TICCIT program.

The two community colleges differed in their approach to staffing sections of mathematics courses on the TICCIT system. At Alexandria instructors assumed responsibility for specific TICCIT classes just as they did for lecture sections. However, classes on the TICCIT system often included some students registered for Algebra I and others registered for Algebra II. The TICCIT program enabled the college to combine students enrolled for different courses under the same instructor, thus forming one full section from multiple courses rather than canceling two or more partial sections. At Phoenix the mathematics faculty achieved even greater flexibility through the TICCIT program. Students arranged their own hours on the TICCIT system rather than registering for particular sections, and instructors were present during the specified hours of system operation. Since both students and instructors chose hours on the TICCIT system, there was no intact section of a group of students with an instructors. Instead students relied heavily on the TICCIT program for their learning. The student-teacher ratio reiterates the importance of the TICCIT program as the primary resource for instruction. Although TICCIT classes of Alexandria's Algebra I and Algebra II conformed to the usual size of lecture sections (20-25 students), there were sometimes 70 students working on the TICCIT system for Phoenix' mathematics courses and only one member of the mathematics department present for support. An increased student-teacher ratio and a reduced ratio of faculty load hours to student contact hours meant that instructors could serve a larger number of students under the TICCIT program.

While instructors responded to students' questions about the subject matter, proctors showed students how to use the TICCIT system. Frequently proctors circulated among students and sought out students in need of assistance. They served as a link to instructors, referring all content questions to a faculty member and resolving mechanical or procedural difficulties by themselves. The proctor acted in a role very much like that of a teacher's assistant. Actually the two proctors hired at Alexandria had qualifications well above the minimum requirements for the position: one had three years of experience in teaching at the secondary-school level and another was a graduate student in a doctoral program in educational technology. The project director at Phoenix adhered closely to the initial specifications for the position as undergraduate students fulfilled the proctor's functions for the TICCIT program. These undergraduate students worked on a part-time basis, with perhaps a dozen students assuming the equivalent of four full-time positions. A description of both proctor and instructor's activities appears later in this report (see Chapter 8: Faculty Acceptance and Teacher Role).

Two other staff members provided the support necessary for the computer system and its peripheral devices. They acted as computer operators and systems engineers in maintaining the TICCIT system and in keeping the system operating in a reliable manner. Seldom was there any lengthy interruption in system service during the demonstration phase of the TICCIT project. Most technical difficulties had been resolved in the initial year of pilot trials for the TICCIT program, and the computer technicians at the colleges had learned procedures for resolving problems quickly.

All together there were at least eight college positions directly related to the TICCIT program: one project director; three faculty members; two proctors; and two technicians. With this staff complement the TICCIT program could not be cost-effective. The slight reduction in instructor costs due to the larger number of students or classroom hours assigned to mathematics faculty did not compensate for the increase in other staff costs. But the pattern for staffing adopted by the two community colleges in the demonstration need not dictate the procedures followed elsewhere. These simply represent two cases of what was done in order to support the TICCIT program, and neither case really is faithful to the developers' projected staffing pattern. However, there should be attention given to the results of this evaluation, particularly those involving course completion rates, before advocating further reductions in instructional staff as a natural consequence of computer applications to teaching.

3.3 Courseware

The courseware employed on the TICCIT system contributed as much to the differences observed between TICCIT classes and lecture-discussion sections as any other component of the program. Students enrolled for courses under the TICCIT program received instruction both innovative in its design and unusual in its manner of delivery. Whether the computer as a delivery mechanism or learner control as a design strategy led to the differences reported in this evaluation is a moot question. The TICCIT program had been conceived as a systematic approach to computer-assisted instruction with each of its components dependent on another. Learner control would be impractical without computer support, and a computer system developed for a particular kind of curriculum materials would be of little value without those materials. The TICCIT program should be viewed as a whole, and the courseware represents not a separate component but rather a highly visible aspect of system capabilities.

This section is a discussion of the TICCIT courseware: its design and its production. More complete accounts of the design and production of courseware for the TICCIT project already exist (Bunderson, 1972, 1975). The description given here just touches upon the processes involved in courseware development in order to convey a sense of those efforts and an appreciation of the TICCIT curriculum.

3.3.a Instructional Design

A basic assumption underlying the design of the TICCIT courseware was that the instructional design followed in developing curricula is independent of the subject matter. If the manner in which a topic is taught is really independent of the topic itself, then the instructional design can be the same regardless of topics or subjects. The developers of the TICCIT program applied the same instructional design to all lessons in mathematics and English. This eliminated the need to specify an instructional strategy for each separate lesson and simplified the process of courseware production.

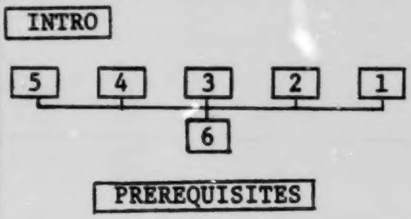
The instructional strategy adopted for the TICCIT courseware depended on maps and learner control. Maps lent structure to the courseware by organizing the content at various levels of detail and by charting the subject matter to be learned. Learner control gave students command over their learning by allowing them to choose, within constraints, topics for study and sequences for instruction. Through maps and learner control the

TICCIT program laid the responsibility for learning on the individual student. The program was a passive, sophisticated resource for learning rather than an active intervention for teaching.

Textbooks offer a familiar parallel for understanding the structure of TICCIT courseware. Just as a textbook has chapters and sections within chapters, the TICCIT courseware has units and lessons within units. Maps in the courseware fulfill much the same function as tables of contents in textbooks: they provide a directory of content coverage. A table of contents, however, simply lists every level of a textbook's material in an outline format. The maps on the TICCIT system present a visual picture of the content coverage at a single level of detail. For example, a course map would show all of the units required for a course just as Figures 1.3 and 1.4 show all of the units in the mathematics and English courseware. And beyond the course map there would be other maps for each unit and then each lesson, leading the student through successive levels of detail in the courseware.

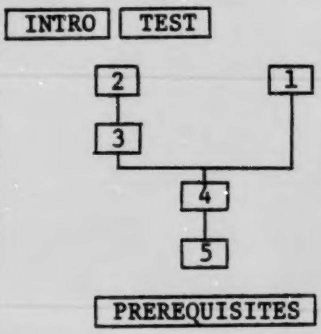
These maps guided and directed student learning. By depicting the formal relationships inherent to the subject matter and employing the color capabilities of the TICCIT system, maps told students what material they had already mastered and where they should go next. A student would first encounter a course map displaying the units of that course, such as the course map for College Algebra given in Figure 3.1. Units toward the bottom of the display served as prerequisites to those which appeared above them. Thus the unit on relations (Unit 11) was a prerequisite to the units on functions and conic sections (Units 9 and 10), and the unit on functions

Course Maps


INTRO
5
4
3
2
1
6
PREREQUISITES

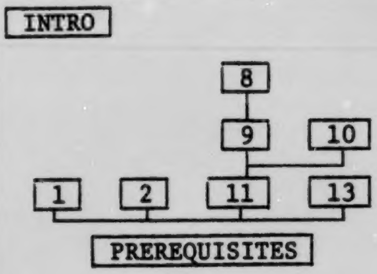
UNIT 10 MAP

1. Hyperbolas
2. Parabolas
3. Ellipses
4. Circles
5. Parallel, Perpendicular and Intersecting Lines
6. Lines and Slopes of Lines


INTRO
TEST
2
1
3
4
5
PREREQUISITES

UNIT 10 LESSON 4 MAP

1. x- and y-Intercepts
2. General Form to Standard Form
3. General Form of Circle to Standard Form
4. Radius, Center, Standard Form
5. Distance Between Points


INTRO
8
9
10
1
2
11
13
PREREQUISITES

MATH 117 MAP

8. Polynomial Functions
9. Functions
10. Conic Sections
11. Relations
13. Matrices
1. Probability
2. Sequences and Permutations

Figure 3.1

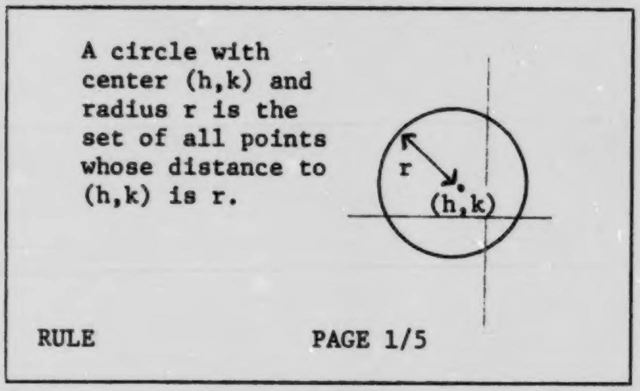
was in turn a prerequisite to the unit on polynomial functions (Unit 8). A unit box colored green meant that a student had demonstrated mastery of that topic and could proceed on to another topic; yellow indicated a need for further work and red was a sign of weakness in student performance. These cues given by placement and color on a display and color held across course, unit and lesson maps. And the sequence of maps shown in Figure 3.1 represents the progression of three maps at the course, unit and lesson levels necessary for accessing a particular lesson in a course, in this case Unit 10 Lesson 4 in College Algebra.

In their form and purpose maps on the TICCIT system resembled learning hierarchies (Gagné, 1970). Like learning hierarchies they imposed structure on the subject matter by suggesting prerequisite relations among topics. This constrained student choices of what material they could study since a red entry on a map prevented access to any component of the map directly above it. Similarly, a yellow box limited access to adjacent topics while a green box permitted the continuation of studies along the hierarchy. It was not until after a lesson map had appeared that instruction took place. Lesson maps contained the finest level of detail on the TICCIT system, segments.

The structure of the courseware gradually led to finer pieces of content: course, unit, lesson and segment. Each successive level could be defined in terms of the next. But segments could not be reduced further. They were the building blocks of the courseware. At the segment level the strategy of learner control truly began.

Basically, each segment consisted of a rule accompanied by examples and practice problems involving the application of that rule. Rules presented students with a definition of a concept or a statement of a principle, as illustrated by the rules given in Figure 3.2. Along with every rule there was a collection of instances of its use. An instance together with a solution served as an example of the rule's application; an incomplete instance called for an answer from the student and provided practice (see Figure 3.3 for illustrations of each type of instance). Both examples and practice problems could be drawn from the same file of instances. This basic rule-example-practice paradigm certainly appears elsewhere. It had been adopted nearly a decade prior to the TICCIT project as an approach to programmed instruction (Evans, Homme & Glaser, 1962). What distinguished the TICCIT program from its predecessors was its combination of learning hierarchies and learner control.

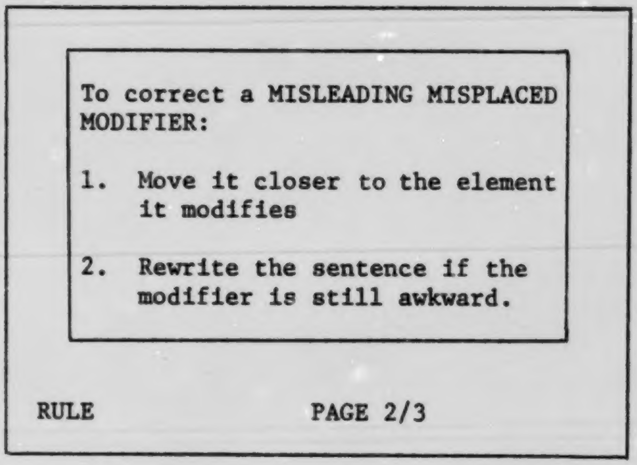
Students on the TICCIT system had control over the rules, examples and practice problems presented to them. The student rather than the computer chose the sequence, difficulty level and frequency of rule and instance displays. Commands corresponding to the three elements of a courseware segment were included on the keyboard for TICCIT terminals (see Figure 1.2). By entering a segment from a lesson map and pressing RULE, EXAMPLE or PRACTICE, a student could exercise control over an instructional sequence. Further, the TICCIT system permitted the student to determine the number of examples and practice problems through repeated key presses as well as their difficulty level through other commands, namely the EASY and HARD keys. For example, a student might first request a statement of the rule (RULE), view several examples of a use (EXAMPLE), proceed to try a number of practice problems (PRACTICE) and progress to more difficult



A circle with
center (h,k) and
radius r is the
set of all points
whose distance to
(h,k) is r.

RULE PAGE 1/5

Definition of a Concept



To correct a MISLEADING MISPLACED MODIFIER:

1. Move it closer to the element it modifies

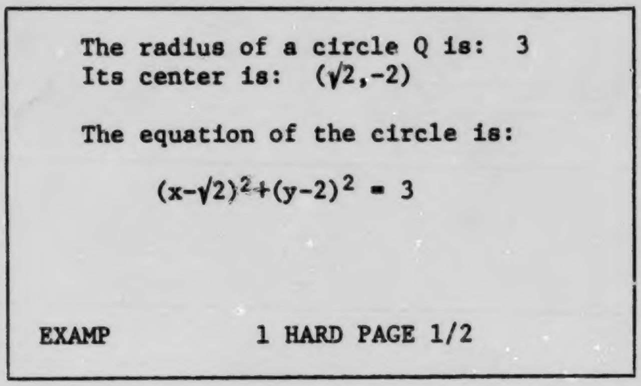
2. Rewrite the sentence if the modifier is still awkward.

RULE PAGE 2/3

Statement of a Principle

Figure 3.2

Rule Displays



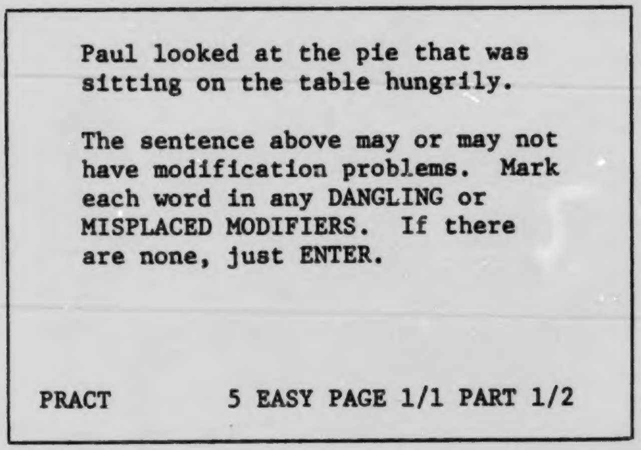
The radius of a circle Q is: 3
Its center is: $(\sqrt{2},-2)$

The equation of the circle is:

$$(x-\sqrt{2})^2+(y-2)^2 = 3$$

EXAMP 1 HARD PAGE 1/2

Example



Paul looked at the pie that was
sitting on the table hungrily.

The sentence above may or may not
have modification problems. Mark
each word in any DANGLING or
MISPLACED MODIFIERS. If there
are none, just ENTER.

PRACT 5 EASY PAGE 1/1 PART 1/2

Practice Problem

Figure 3.3

Instance Displays

problems (HARD). Alternatively, a student confident in his or her knowledge of the topic could start a segment by answering practice problems or a student unsure about a concept might want to review a large number of examples at different levels of difficulty before attempting any problems. (Descriptions of students' use of the learner control options available on the TICCIT program can be found in Chapter 7: Student Activities.) When a student had demonstrated mastery by responding correctly to a sufficient number of practice problems with the correct answers, the student's lesson map became green for that particular segment.

Courseware maps took students through the structure of the TICCIT curriculum and left them at segments. At this level the learner control of the TICCIT system came into play. The options available to each student affected the sequence, difficulty level and frequency of rule and instance displays. The TICCIT system provided students with the opportunity and responsibility to take command over the instruction presented to them. Additional features on the TICCIT system helped students in managing their learning. There was a component of learner control which gave further assistance upon student request (HELP). Such assistance could result in a simpler explanation of a rule, a gradual and detailed presentation of an example, or an answer to a practice problem. If a student was uncertain about what to do next, the system could suggest an appropriate choice dependent on that student's previous performance (ADVICE). And the system had videotape, color, graphic and audio capabilities for strengthening its presentations.

3.3.b Courseware Production

The uniform nature of the instructional design adopted for the TICCIT program made it possible for the courseware developers to establish a production model for the curriculum. Regardless of subject matter, all courseware adhered to the same form of map structures and included the same features at the segment level. This consistency in design encouraged the assembly of courseware production teams, with each member of the team assigned specific tasks. The teams brought together persons with different fields of expertise so that members could contribute their own special skills to resolving problems in curriculum development. Such an approach was a marked departure from usual methods of developing curriculum materials. It was an explicit attempt to establish a model for the efficient production of high quality curriculum materials for computer-assisted instruction.

A fresh approach to curriculum development was demanded by the ambitious scope of the TICCIT project. Within two years courseware sufficient for supporting at least four full courses in mathematics and English had to be completed and set in place at community colleges. And numerous questions affecting the development of those materials had to await progress in developing the computer system and in arriving at content specifications in line with the colleges' curriculum. There had to be a courseware production model capable of rapid curriculum development. The courseware developers hoped to achieve this efficiency with production teams and standard forms for all materials.

Each production team was to include representatives of six specialized skills. An overview of these six types of team members and their respective responsibilities appears in Figure 3.4. Since they had actually specified the instructional design for the TICCIT program, the instructional psychologists naturally assumed responsibility for insuring that all courseware adhered to the structure of maps and to the strategy of learner control. Persons fulfilling this role brought exceptional strengths in educational psychology and computer applications to the production teams.

Much of the real burden of curriculum development fell upon the subject matter experts. They supplied the content specifications for the courseware and developed the maps of content coverage. In developing courseware maps the subject matter experts began at the level of the full curriculum (see Figures 1.3 and 1.4) and proceeded down to the level of segments where specific rule statements and instances of their application appeared. These members of the production team typically had advanced degrees in either mathematics or English and had taught college courses in their particular field. The community college authors, those instructors released for six months to join the production teams, functioned as subject matter experts.

Instructional design technicians provided a critical link between curriculum development and courseware production. They received content specifications, in the form of courseware maps with some exemplary rule statements, from the subject matter experts and then expanded upon these rough drafts so that other members of the production team could construct the files of rules, examples and practice problems. This required defining the critical attributes of each rule and developing specific guidelines for the construction of different instances of its use. The definition of each

Team Member	Major Responsibility
Instructional Psychologist	Providing guidance in the production of courseware consistent with the instructional design of the TICCIT program.
Subject Matter Expert	Structuring the curriculum in terms of courseware maps and drafting statements of the rules and concepts to be learned.
Instructional Design Technician	Completing specifications for rules, examples and practice problems in accordance with the options built into the strategy of learner control.
Authoring Assistant	Generating files of rules and instances to meet the courseware specifications.
Packaging Specialist	Preparing curriculum materials for display by computer.
Empirical Design Technician	Validating the instructional quality of the courseware.

Courseware Production Team

Figure 3.4

rule's attributes had to be fine enough to suggest what courseware should be made available in response to the various options of TICCIT's learner control (e.g., HELP, EASY, HARD). Graduate students in instructional psychology served as instructional design technicians in developing these detailed courseware specifications.

Next in the flow of courseware production came the authoring assistants and the packaging specialists. Authoring assistants, usually chosen on the basis of an undergraduate degree in the subject matter and relevant experience, received the courseware specifications and generated the necessary rules and instances. Packaging specialists, typically undergraduate students employed on a part-time basis, polished the final product and generally made the courseware ready for computer display. The supervisor of these specialists had to understand the display capabilities of the TICCIT system, such as its color capacity, graphics support and audio messages, and decide when it was appropriate to use them. Finally, the empirical design technician was to validate the instructional quality of all materials.

From a simplified description of the production team it may seem as though the process of curriculum development was itself smooth and orderly. Seldom did the reality of curriculum development closely resemble the "ideal" production model. That original model of a factory for courseware production (Low, Graves, Stilson & Jacobsen, 1972) had gone so far as to specify the piecemeal assembly of a curriculum at 20 work stations. There were to be certain members of the production team responsible for completing a given task at each work station. The detail and specificity involved in courseware production perhaps facilitated the process of curriculum development but also almost certainly contributed to some of the problems encountered by the developers.

Without closure on the instructional design of the TICCIT program or the capabilities of the TICCIT computer system, interruption and delay were inevitable. The most persistent problem in the early history of the TICCIT project was the concomitant development of the computer system and the curriculum materials. Often the engineers did not know what specifications their computer system had to meet while the courseware developers were uncertain about what could be expected of the computer system. And the physical separation of the system engineers and courseware developers only aggravated their respective uncertainty. The courseware developers had to commit themselves to an instructional design in order to define the computer support which would be required by the curriculum. There was no opportunity to benefit from trial and error in defining the initial TICCIT system. Quite obviously a prototype computer system for exploring the ramifications of different alternatives in instructional design would have been desirable.

At times the specialization inherent to the approach to curriculum development as a production process impeded progress. There was insufficient interaction among members of the production teams. Each specialist tended to contribute just one type of expertise without appreciating how that expertise might best blend into the production process. Yet a knowledge of the entire process was essential if a subject matter expert, for example, was to develop content specifications that could later take advantage of the display capabilities of the computer system, since color and graphics could be powerful cues in learning or fanciful distractors of student attention. Deciding how different specialties might complement rather than detract from one another, and recognizing what constraints had to be met at various stages in the process of curriculum development, required close collaboration among members of the production teams.

There were also frequent changes in the roles and responsibilities of team members in response to schedule demands and staff attrition. As deadlines approached for the completion and release of courseware, subject matter experts became team leaders responsible for implementing their own production models and for producing particular lessons. One subject matter expert found it most expedient to act as an individual author since he had a strong command of the entire production process. Another subject matter expert chose to stay with the original production model and rely heavily on other members of his production team. And a third production team had a succession of subject matter experts, each with a somewhat different view of an appropriate structure for the courseware. The original production model seemed too cumbersome for easy adaptation to tight deadlines or staff work styles.

Validation of the courseware took place at the community colleges as faculty reviewed the courseware and students took courses under the TICCIT program on an experimental basis. Formative evaluation become largely a matter of identifying errors and recommending changes to strengthen the curriculum. The courseware developers made the necessary revisions and considered further improvements if their resources would permit the changes. In the place of a formal evaluation prior to the demonstration phase of the project there was extensive review and revision. Resources had to be devoted to the completion of all courseware rather than its refinement. Thus there was scant opportunity to validate mastery tests embedded at the lesson level or to prove the efficacy of the courseware maps as learning hierarchies. Instead *a priori* judgments of what performance constitutes mastery had to be accepted and initial decisions about the logical structure of the subject matter had to hold.

Despite these problems the courseware developers completed a curriculum equivalent to five full courses. It made mainline instruction possible in those mathematics and English courses with the highest student enrollments. And it gave students control over their own instruction along with responsibility for their own learning. The final product embodied the expertise of diverse disciplines and represented the culmination of an innovative and ambitious project.

3.4 Summary

The developers of the TICCIT program approached the problems of implementing computer-assisted instruction in schools in a systematic manner. Each step in the process of introducing the TICCIT program into the school curriculum had been carefully planned. There was a sound rationale for choosing community colleges as the level of education most conducive to a market success for computer-assisted instruction. And there were explicit criteria for selecting particular community colleges as demonstration sites for the project. To maintain the commitment of these sites and to prepare them for the adoption of the TICCIT program, the developers established specific procedures. These procedures involved the community colleges in the administration of the project on a regular, active basis. Similarly, the design and production of the TICCIT courseware reflected a systems approach to curriculum development. All materials made available under the TICCIT program followed the same instructional design. Such consistency in design enabled the developers to specify a single production model for the entire curriculum. In all respects, including curriculum development, the TICCIT program was a systematic application of computer-assisted instruction.

Enrollment in community colleges had tripled in the decade prior to the start of the TICCIT project. Projections indicated that it would double within another decade. Unlike other sectors of education, there was rapid growth in student enrollment at community colleges. Furthermore, a high proportion of the total enrollment occurred in introductory mathematics and English courses. By concentrating on just a few select courses, the TICCIT program could supplant as much as one-fifth of a college's traditional curriculum. This would simply be equivalent to full-time students taking one mathematics or English course under the TICCIT program in each academic term of their studies. And the policy of open admissions so common at community colleges had created a persistent search for better ways to teach students basic skills in mathematics and English. Community colleges, then, represented the high-volume market necessary for commercial success with computer-assisted instruction.

The particular community colleges selected as demonstration sites had to meet certain criteria. Foremost among these criteria for selection was geographic proximity to the developers. The installation of a new computer system and the introduction of a new curriculum program were apt to require heavy external support for the community colleges. Another important factor taken into consideration was the college's capacity to accommodate the project. There had to be sufficient physical space for the computer system and student carrels, competent staff available to support the program's use, and a high enough enrollment in the target courses to justify a need for 128 terminals. Several colleges otherwise qualified to become participants in the project had student populations unlike the national norms in their characteristics. The developers of the TICCIT program sought and found demonstration sites that would be representative of community colleges in general.

Formal agreements reached with the demonstration sites stipulated that there would be several steps taken to insure the smooth and orderly transition of the TICCIT program into the college curriculum. Notable among these were: the appointment of local project directors at the colleges and a person responsible for college liaison for the developers; the establishment of a committee with senior representatives of each participant to oversee the project; the development of an implementation plan with specific details on the preparation, installation and operation of TICCIT systems at community colleges; and the participation of community college instructors in developing content specifications for the TICCIT courseware. Each of these steps helped to make the community colleges active participants in the project with a definite role in project administration and planning. Later the colleges devoted significant amounts of their own resources toward completion of the TICCIT program.

In order to develop a curriculum equivalent to five full community college courses, the developers of the TICCIT courseware adopted a systematic approach to the design and production of curriculum materials. Each component of the TICCIT curriculum, regardless of content coverage, adhered to the same basic instructional design. That design depended heavily on maps, similar to learning hierarchies, to lend structure to the subject matter. A series of three maps depicting progressively finer levels of detail in the subject matter graphically charted the content coverage of TICCIT courseware. Learner control became available at the finest level of detail, the segment. Each segment contained a rule along with examples and practice problems illustrating the application of that rule. Through options built into the TICCIT system a student could exercise control over the sequence, difficulty level and frequency of rule and instance displays.

The uniform nature of this instructional design across the TICCIT courseware invited the application of a single production model for the entire curriculum. The courseware developers assembled production teams including members with different specialty skills, and they defined a production process specifying the flow of the curriculum along work stations. This approach to curriculum development was meant to facilitate the rapid production of high quality courseware. It did encourage contributions from persons with different fields of expertise, and it did result in the completion of a curriculum comparable in coverage to five full courses. But there were numerous changes to the original production model along the way to these accomplishments. Some became necessary because courseware production took place concomitantly with development of the computer system. Others occurred because the production model was too rigid for adapting easily to schedule demands and work styles.

This chapter has concentrated on the processes involved in implementing the TICCIT program at community colleges and in developing its curriculum. Also presented were descriptions of the student populations at the demonstration sites, the target courses for this evaluation, the procedures for student placement in comparison groups, and the colleges' staff for the TICCIT program. The chapters which follow report the results attained by the TICCIT program in terms of its impact on student performance.

Chapter 4

Course Completion Rates

Although student achievement is generally accepted as the single, most important measure of program success, there is an even more direct measure of educational impact. It is simply whether or not a student completes the work required under a program. In a way this is a very rough indicator of achievement since any passing grade signifies completion and all else becomes noncompletion. Yet it is an indicator with direct consequences for students and schools. A student who fails to complete a course may not advance to higher level courses in the same subject or perhaps not fulfill requirements for promotion or graduation. Repetition of courses or failure to satisfy school standards in turn affect a school's productivity: what proportion of students starting a program of studies actually completes it.

Such completion rates seem especially important for the community college. Here is an institution which must cope with a heterogeneous student body, often with deficiencies in basic skills, and prepare these students for an occupation or further academic work. The TICCIT program addressed precisely those skills which represent a significant component of the community college curriculum and seem always to call for improved teaching methods. The colleges that participated in the TICCIT project did so at least in part to find improved teaching methods for their courses in algebra and composition. And the colleges definitely sought a curricular program that would enable a larger percentage of students to complete courses in algebra and writing. Indeed completion rates above those associated with lecture classes were one of the stated goals of the TICCIT program.

Besides representing program productivity and participants' concerns, completion rates can affect the composition of our comparison groups. Some students certainly will not finish their course and so be absent from posttesting. As long as the characteristics of those present for posttesting remain independent of their instructional condition, the comparison of student achievement under one program with that under another should be fair and accurate. Even when programs lead to significantly different completion rates, achievement analyses can be free of bias. It is when course completion depends on a student trait, such as entrance ability, under one condition but not another that possible contamination of other data occurs. Then achievement analyses would be subject to the programs' differential effects on completion, and completion rates would be the only unbiased measure of program impact.

For these reasons our first chapter on the outcomes of the TICCIT project concerns course completion rates. It begins with a section about the meaning of completion. Completion is not the simple complement of attrition nor is it an entirely unambiguous measure. So we need to explain what we mean by course completion rates. The chapter continues with a description and analysis of results. Given quite different results dependent on the course conditions (i.e., classroom instruction or TICCIT program) it is appropriate to take completion a step further and look at enrollment trends in the next academic term. This chapter closes with a discussion of the factors that contributed to our findings and the implications of these results.

4.1 The Nature of Completion

Admittedly completion might be defined in several different ways. No one definition is likely to fit all circumstances or suit all purposes. With that in mind let us state our preference: a course completion rate is the ratio of students who receive credit for a course to all those who initially enroll for the course. On a final grade sheet it is the number of passing grades in relation to total class size. For example if a class has 32 students listed on the official college rolls and 24 of them receive A,B,C or D grades, the completion rate would be .75 or 75% of initial enrollment. It is a seemingly simple concept. But completion viewed in this manner and attrition taken as students who drop out of a course hardly account for all students.

Especially at colleges with a policy of open enrollment and a commitment to service for the local community there is a sizeable percentage of students somewhere between completion and attrition. These students attend classes regularly and yet fall short of fulfilling requirements for course credit. In one sense such students have completed the course since they were in attendance at both the start and end of an academic term. Obviously they did not drop out of the course and so would not be part of attrition. But completion should imply something beyond mere attendance: it also suggests that a student has satisfied all course requirements. It is, as we said, a measure of productivity. Neither the student who withdrew from a course or the one who failed to meet course standards for credit would qualify as a completion.

This may appear to be a particularly harsh definition for programs which purport to allow for individual differences among students. Such programs frequently let a student proceed through a course at his own pace. A school might then assign a nonpunitive grade to students who fail to finish all of the required course work within an academic term. Typically this grade carries no penalty in terms of grade point average or class standing but makes it necessary for students to enroll in the course again and complete all work in order to receive credit. A reenroll grade is a step toward recognition of differences among students in their learning rates. It might then be argued that it is inappropriate to evaluate completion rates under a self-paced system of instruction like the TICCIT program within the fixed time constraints of an academic term. Certainly the argument is a legitimate one if the proportion of students who eventually achieve mastery matches or exceeds that for completion in a lecture-discussion condition.

All of our tables with summary figures on completion therefore present alternative interpretations for calculating rates. One alternative gives the benefit of doubt about a student's eventual status to the TICCIT program. It counts students still attending classes at the end of a term as completions. The analyses for completion as a program outcome, however, use the more restrictive definition of fulfilling all requirements for course credit within an academic term. But these analyses do include a variable that would indicate the success of students reenrolling in a course apart from those just starting. We favor a restrictive interpretation of completion as it reflects productivity within fixed time constraints and is borne out by data across terms.

4.2 College Grades and Rosters

The source of our data about students completing a course was the college roster. An emphasis other than the receipt of course credit might lead to a different approach to documenting completion. If our primary interest were attendance, it would be more appropriate to keep daily attendance records. These would show attrition as well as the regularity of attendance clearly. Should we accept some minimal level of student achievement as evidence of completion, then posttesting would be sufficient. But the official college rosters seem to incorporate these features in various course grades and the final roster with grades represents the definitive statement on student status.

Probably every type of administrative record has inaccuracies that occur somewhere along the line in its construction. As a general rule the care taken in the preparation of final grades avoids error on college rosters. What did occur in our data were inconsistencies in section assignments and grade requirements. Sometimes an instructor will ask a colleague to admit a student registered for one class into another. Such an occurrence is infrequent but it would seem from Table 4.1 that this courtesy reached epidemic proportions at Alexandria in introductory algebra. Actually it was quite easy for an instructor to recommend that a student encountering some difficulty try the course under an independent study format. These exceptions to the instructional condition that held for the rest of the students in a section came to our attention through other sources of evaluation data (e.g., online records, student interviews). And although 21 students listed in lecture sections pursued their course work under programmed conditions, individual cases like these stood with the condition corrected in our analyses for completion as a program outcome. None of the math courses at Phoenix or the English courses at either demonstration site had inconsistencies in section assignments even close in total to those of the introductory algebra course at Alexandria.

Another kind of inconsistency within sections involved class size. It too occurred primarily at one college in one subject. Often the class rosters released early in the academic term listed a larger number of students than the later rosters with final grades. Students who never came to a class or dropped shortly after the term began were deleted from the official rosters. Thus later rosters gave accurate class sizes, and obscured possible differences in attrition early in a term.

Math 31: Algebra I at Alexandria
Academic Year 1975-76

Instructional Condition for Course Sections		Instructional Condition for Individual Students (Exceptions to Class Condition)		
		TICCIT	Programmed	Lecture
Fall Quarter	TICCIT	—	6	2
	Programmed	2	—	0
	Lecture	0	15	—
Winter Quarter	TICCIT	—	10	1
	Programmed	0	—	0
	Lecture	1	1	—
Spring Quarter	TICCIT	—	4	0
	Programmed	3	—	0
	Lecture	1	5	—
Totals	TICCIT	—	20	3
	Programmed	5	—	0
	Lecture	2	21	—

Exceptions to Class Conditions

Table 4.1

Across sections there were differences in grading standards. One instructor might assign A grades to a much larger percentage of students than another instructor would. Whether a grade was an A,B,C or D had no effect on our dichotomized variable for completion. This equivalence of all passing grades cancelled out most, if not all, variations among instructors in grading practices. Even if an instructor chose to give a student who fell short of fulfilling course requirements a grade usually reserved for withdrawal instead of one better suited to reenroll status, there would still be no effect in terms of our preferred definition for completion. Any grade other than those that carried course credit simply indicated a zero value for our completion variable.

Simplifying grades to only two values omits some information. There were really five distinct and different grades assigned by instructors. Firstly, the grades that went to students who fulfilled course requirements and, therefore, received credit were A,B,C and D. Secondly, the grade associated with unacceptable work and failure was, naturally, F. In the developmental math sequence at Alexandria these two extremes were S for satisfactory performance and U for unsatisfactory. A grade of W for withdrawals was a third classification shared by both colleges. It usually meant that a student had changed sections, withdrawn from the course, or been dropped by the instructor due to excessive absences. Occasionally a student would miss a final exam or neglect just one aspect of a course's requirements, or come very close to completing all course work under independent study. Such students received a grade of incomplete (I at Alexandria and X at Phoenix) that forced them to fulfill their outstanding course obligations in order to receive credit. This fourth type of grade was given only when instructors expected students to complete the course within a matter of a few weeks at most. It reverted to a withdrawal on the student's record if he did not complete his outstanding obligations by a deadline prescribed by college policy. In cases where students had made progress in the course but not enough to warrant either a grade with credit or an incomplete, instructors gave a grade requiring students to enroll in the course again in order to receive credit. These reenroll grades (R at Alexandria and Z at Phoenix) were common among students in the independent study programs already at the colleges. Alexandria offered introductory algebra in a programmed instruction format and Phoenix had an audio-tutorial program for its sequence of algebra courses.

Of course, college rosters with final course grades were not the sole source of our data about completion. They provided our measure of the program outcome taken as having a value of one for students who received course credit and zero otherwise. For this to be a fair representation of an effect dependent on the treatment we also needed comparison groups formed on a random basis or at least measures suitable for identifying similar students in the groups. Students at Phoenix were randomly assigned to conditions, subject to their consent, in the fall semester of 1975. In other terms procedures were at best quasi-random and so background data such as grade point average and sex were collected in addition to routine pretests. These independent variables served as rough benchmarks in checking group similarity and as covariates in estimating treatment effects.

4.3 Presentation of Results

As part of the evaluation there were routine summaries of grade distributions and course completion rates. These were prepared from the college rosters issued immediately after the close of an academic term. The rosters had final grades for that academic term and therefore reflect completion within that fixed time constraint. No attempt was made to update these rosters later since those grades subject to change, namely incompletes, represented only about five percent of the total distribution. And our emphasis was on completion as a reflection on productivity. Still it is worthwhile to consider the possible changes if all students assigned a grade of incomplete subsequently met their outstanding requirements and received course credit. One of our alternative interpretations for completion goes even further and credits grades of incomplete and reenroll as completions from the standpoint of attendance.

Each summary of course grades also presents three completion rates. The first corresponds to our preferred definition of completion as the proportion of grades with credit to total enrollment. The appropriate calculation is then simply the number of A,B,C and D grades divided by the total number of students listed on the official class roster. This interpretation makes no distinction between the total number of students registered for a course and the number who actually attend classes and put forth an effort toward learning. A second rate therefore incorporates an approximate correction for early withdrawal and nonattendance. Our version of a corrected completion rate again has the number of grades with credit as its numerator but the denominator is reduced by the number of withdrawals. The expected result of this adjustment is always a higher estimate. The most optimistic and least stringent view of completion is our third rate. It is the ratio of grades with credit plus grades of incomplete or reenroll to total class size. In one sense this represents an attendance rate as its complement is largely the rate of withdrawal. In another it represents a maximum completion rate independent of time if we assume that all students with incomplete and re enroll grades eventually earn course credit.

These three completion rates as well as grade distributions by section and totals by condition appear in Appendix M. There is a table for each course in which the TICCIT program constituted a curricular alternative. These figures cover the implementation and demonstration periods of the project. It might be noted that, in this appendix and elsewhere, our references to sections through a convention of arbitrary numbers remain consistent. Thus, results in terms of completion, achievement and attitudes can be cross-referenced for a particular section.

To elaborate now on results for individual sections would only further delay presenting data on program outcomes. It is probably sufficient to cite a few general trends. Especially for math courses there was a high degree of consistency among sections under the same condition. Completion rates for classes on the TICCIT system seem relatively stable across sections, courses and colleges with slight increases across terms. However, there was a difference in section rates dependent on subject matter. Courses in writing usually led to a somewhat higher percentage of students with credit than math courses. Indeed the proportion of students with credit more than doubled between math and English classes on the TICCIT system. Generally there was greater consistency across subjects under the lecture-discussion condition. Within a course certainly there was much less variation among sections under the same condition than between conditions. These trends appear more clearly in the summary tables that follow.

4.3.a Math Courses

Tables 4.2 and 4.3 present the grade distributions and course completion rates for math courses at Phoenix and Alexandria. Because students were randomly assigned to comparison groups in the fall semester and nearly

Course Completion Rates
Phoenix
Math 007, 106, 108 and 117
Academic Year 1975-76

			Grade Distribution												
			Credit (A,B,C,D)		Failure (F)		Incomplete (X)		Re-enroll (Z)		Withdraw (W)		Completion Rates		
Term and Course	Comparison Group	Number of Students	N	%	N	%	N	%	N	%	N	%	I	II	III
Fall Semester:															
Math 007	Total	572	196	34	7	1	8	1	202	35	159	28	.34	.47	.71
	TICCIT	215	27	13	0	0	2	1	136	63	50	23	.13	.16	.77
	Lecture	357	169	47	7	2	6	2	66	18	109	31	.47	.68	.68
Math 106	Total	307	107	35	2	1	2	1	104	34	92	30	.35	.50	.69
	TICCIT	144	34	24	0	0	1	1	80	56	29	20	.24	.30	.80
	Lecture	163	73	45	2	1	1	1	24	15	73	39	.45	.73	.60
Math 108	Total	160	52	32	0	0	2	1	62	39	44	27	.32	.45	.72
	TICCIT	76	10	13	0	0	2	3	52	68	12	16	.13	.16	.84
	Lecture	84	42	50	0	0	0	0	10	12	32	38	.50	.81	.62
Spring Semester:															
Math 007	Total	484	181	37	6	1	25	5	134	28	138	29	.37	.52	.70
	TICCIT	195	31	16	2	1	23	12	82	42	57	29	.16	.22	.70
	Lecture	289	150	52	4	1	2	1	52	18	81	28	.52	.72	.71
Math 106	Total	298	101	34	2	1	19	6	84	28	91	37	.34	.49	.68
	TICCIT	135	15	11	0	0	19	14	61	45	40	30	.11	.16	.70
	Lecture	163	86	53	2	1	0	0	23	14	51	44	.53	.77	.67
Math 108	Total	201	62	31	1	0	14	7	60	30	63	31	.23	.34	.60
	TICCIT	85	11	13	1	1	13	15	45	53	15	18	.13	.16	.81
	Lecture	116	51	44	0	0	1	1	15	13	48	41	.44	.75	.58
Math 117	Total	222	115	52	0	0	12	5	33	16	62	28	.52	.72	.72
	TICCIT	61	14	23	0	0	11	18	16	26	20	32	.23	.34	.67
	Lecture	161	101	63	0	0	1	1	17	11	42	26	.63	.85	.74
Summer Semester:															
Math 106	Total	131	49	37	0	0	19	15	39	30	24	18	.37	.46	.82
	TICCIT	50	8	16	0	0	19	38	12	24	11	22	.16	.21	.78
	Lecture	81	41	51	0	0	0	0	27	33	13	16	.51	.60	.84
Math 117	Total	75	31	41	2	3	12	16	13	16	17	23	.41	.53	.77
	TICCIT	36	8	22	0	0	10	28	8	22	10	28	.22	.31	.72
	Lecture	39	23	59	2	5	2	5	5	13	7	18	.59	.72	.82

Completion Rates: I (A,B,C,D)/N II (A,B,C,D)/N-W III (A,B,C,D,X,Z)/N

Table 4.2(a)

Course Completion Rates
Phoenix
Totals across Math Courses and Semesters
Academic Year 1975-76

			Grade Distribution													
			Credit (A,B,C,D)		Failure (F)		Incomplete (X)		Re-enroll (Z)		Withdraw (W)		Completion Rates		
Term and Course	Comparison Group	Number of Students	N	%	N	%	N	%	N	%	N	%	I	II	III
Fall Semester:															
All Courses	Total	1039	355	34	9	1	12	1	368	35	295	28	.34	.48	.71
	TICCIT	435	71	16	0	0	5	1	268	62	91	21	.16	.21	.79
	Lecture	604	284	47	9	1	7	1	100	17	204	34	.47	.71	.65
Spring Semester:															
All Courses	Total	1205[3]	459	38	9	1	70	6	311	26	354	29	.38	.54	.70
	TICCIT	476	71	15	3	1	66	14	204	43	132	28	.15	.21	.72
	Lecture	729	388	53	6	1	4	1	107	15	222	30	.53	.77	.68
Academic Year:															
Math 007	Total	1056	377	36	13	1	33	3	336	32	297	28	.36	.50	.71
	TICCIT	410	58	14	2	0	25	6	218	53	107	26	.14	.19	.73
	Lecture	646	315	49	11	2	8	1	118	18	190	29	.49	.69	.68
Math 106[1]	Total	736[3]	257	35	4	1	40	5	227	31	207	28	.35	.49	.71
	TICCIT	329	57	17	0	0	39	12	153	47	80	24	.17	.23	.76
	Lecture	407	200	49	4	1	1	0	74	18	127	31	.49	.71	.68
Math 108	Total	361[3]	114	32	1	0	16	4	122	34	107	30	.32	.45	.70
	TICCIT	161	21	13	1	1	15	9	97	60	27	17	.13	.16	.83
	Lecture	200	93	46	0	0	1	0	25	12	80	40	.46	.77	.59
Math 117[2]	Total	297	146	49	2	1	24	8	46	15	79	27	.49	.67	.73
	TICCIT	97	22	33	0	0	21	22	24	25	30	31	.23	.33	.69
	Lecture	200	124	62	2	1	3	1	22	11	49	24	.62	.82	.74
All Courses	Total	2450[3]	894	36	20	1	113	5	731	30	690	28	.36	.51	.71
	TICCIT	997	158	16	3	0	100	10	492	49	244	24	.16	.21	.75
	Lecture	1453	736	51	17	1	13	1	239	16	446	31	.51	.73	.68

Completion Rates: I (A,B,C,D)/N II (A,B,C,D)/N-W III (A,B,C,D,X,Z)/N

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[1] These totals include the fall, spring and summer semesters.

[2] Totals for Math 117 reflect only the spring and summer semesters.

[3] Two students audited a math course so the total number of students differs by two with the total number of grades. Both students were in lecture classes in the spring semester: one in Math 106, and another in Math 108.

Table 4.2(b)

Course Completion Rates
Alexandria
Math 31 and Math 32
Academic Year 1975–76

Grade Distribution

Term and Course	Comparison Group	Number of Students	Credit (S)		Failure (U)		Incomplete (I)		Re-enroll (R)		Withdraw (W)		Completion Rates		
			N	%	N	%	N	%	N	%	N	%	I	II	III
Fall Quarter:															
Math 31	Total	239	59	25	40	17	0	0	103	43	37	15	.25	.29	.68
	TICCIT	116	10	9	18	16	0	0	73	63	15	13	.09	.10	.72
	Programmed	44	5	11	5	11	0	0	24	55	10	23	.11	.15	.66
	Lecture	79	44	56	17	22	0	0	6	8	12	15	.56	.66	.63
Winter Quarter:															
Math 31	Total	215	64	30	23	11	15	7	78	36	35	16	.30	.36	.73
	TICCIT	118	29	25	11	9	11	9	55	47	12	10	.25	.27	.81
	Programmed	46	13	28	6	13	3	7	16	35	8	17	.28	.34	.70
	Lecture	51	22	43	6	12	1	2	7	14	15	29	.43	.61	.59
Math 32	Total	76	17	22	6	8	0	0	36	47	17	22	.22	.29	.70
	TICCIT	42	2	5	6	14	0	0	28	67	6	14	.05	.06	.71
	Lecture	34	15	44	0	0	0	0	8	24	11	32	.44	.65	.68
Spring Quarter:															
Math 31	Total	173	39	23	14	8	15	9	54	31	51	29	.23	.32	.62
	TICCIT	57	13	23	2	4	11	19	20	35	11	19	.23	.28	.77
	Programmed	71	14	20	7	10	2	3	22	31	26	37	.20	.31	.54
	Lecture	45	12	27	5	11	2	4	12	27	14	31	.27	.39	.58
Math 32	Total	86	32	37	8	9	7	8	27	31	12	14	.37	.43	.77
	TICCIT	42	6	14	3	7	7	17	19	45	7	17	.13	.17	.76
	Lecture	44	26	59	5	11	0	0	8	18	5	11	.59	.67	.77
Academic Year:															
Math 31	Total	627	162	26	77	12	30	5	235	37	123	20	.26	.32	.68
	TICCIT	291	52	18	31	11	22	8	148	51	38	13	.18	.21	.76
	Programmed	161	32	20	18	11	5	3	62	39	44	27	.20	.27	.61
	Lecture	175	78	45	28	16	3	2	25	14	41	23	.45	.58	.61
Math 32	Total	162	49	30	14	9	7	4	63	39	29	18	.30	.37	.73
	TICCIT	84	8	10	5	6	7	8	47	56	13	15	.10	.11	.74
	Lecture	78	41	5	9	12	0	0	16	21	16	21	.53	.66	.73

Completion Rates: I S/N II S/N-W III S+R+I/N

Table 4.3

1000 students enrolled for math courses with the TICCIT program, Phoenix provides a stronger test case for examining TICCIT's effects on course completion. And the effect was dramatic. For the first course listed in these tables, Phoenix's Math 007 in the fall semester of 1975, only 27 of the 215 students who had registered for the course under the TICCIT condition actually received grades high enough to carry credit. This completion rate of 13% stands in sharp contrast to the lecture rate of 47%. Yet the course and term of this example represent the highest enrollment and the best control in the evaluation. It behooves us to take a closer look at the fall results for this introductory algebra course.

Several plausible explanations aside from a treatment effect might be offered as alternative causes of the sizeable gap in completion rates between the TICCIT and lecture conditions. Let us try to consider some of them now and hold others until coming to the analyses for completion. One prominent explanation might be the use of an inappropriate procedure in calculating completion rates. There seems no better source than official class rosters so we must turn to other interpretations of completion. Perhaps withdrawals unfairly affected the TICCIT condition and an adjustment for attrition would ease the difference. The second type of completion rate takes an approximate correction for attrition into account: it deducts the number of withdrawals from total enrollment. But the completion rates under this interpretation become 16% for the TICCIT condition and 68% for lecture classes. Corrections for attrition seem to exacerbate rather than ease the difference.

The problem may lie instead with our insistence on a fixed time constraint for a self-paced program. If we were to relax this constraint and anticipate completions beyond the arbitrary deadline of an academic term, rates under the TICCIT condition would improve. The high percentage of reenroll grades in the TICCIT condition suggests that there is merit to this position. For Math 007 in the fall semester of 1975 reenroll grades constituted 63% of the TICCIT grade distribution and 18% of the distribution for the lecture condition. The third type of completion rate reflects this fact. When we consider reenrolls and incompletes as eventual completions, the rate changes to favor the TICCIT program. The figure for TICCIT classes is 77% as compared to 68% for traditional classes. At least in terms of attendance from the start to the conclusion of an academic term there is a slight advantage to the TICCIT program over classroom instruction. To take this argument a step further and imply a similar advantage in terms of completing a course with credit would be unwarranted.

It cannot be assumed that all students who receive a grade equivalent to one that necessitates subsequent enrollment in order to receive credit do both later enroll and earn course credit. Of the 136 students with Z grades from TICCIT sections of Math 007 from the fall semester, 58 students enrolled for Math 007 again in the spring term (see Appendix N on subsequent term enrollment). Already the potential for eventual completion has reduced the most optimistic fall rate to about 40% instead of 77%. It is even less since only 31 students completed Math 007 under the TICCIT program in the spring semester. Since nearly every student who did reenroll followed the same instructional condition, a "best case" estimate of completing introductory algebra after enrolling in the course for a second term would be 31 of 58 students or slightly better than a student's probability of completing the same course within one term in a regular classroom format. But only 10 of these 31 students were actually repeating the course. So the completion rate among students reenrolling for introductory algebra in the spring semester was 17%

(10 grades with credit for 58 students) and it was 15% for students enrolling in the TICCIT program for the first time (21 grades with credit for 137 students). The close similarity in completion rates among students repeating courses and those enrolling for the first time will be seen again in the analyses for this program outcome.

As long as completion is viewed as the receipt of a course grade carrying college credit, the rate for the TICCIT program remains well below that of lecture classes. When adjusted for attrition the completion rates between conditions differ by an even greater margin. The primary reason for this difference is the much larger group of students who remain in a TICCIT class but fail to satisfy course requirements within an academic term. Yet when these students take the same course in a subsequent term, their rate of completion after a second term seems hardly better than that of students enrolled for the first time. Only if we accept attendance at the beginning and end of a term as sufficient for completing a course does the rate for the TICCIT program exceed that for the familiar lecture format. Otherwise the mechanics of computing completion rates seem not to offer an explanation of the difference between conditions.

Perhaps the cause underlying the difference observed in Math 007 for the fall semester relates to the nature of the TICCIT program for that course, term and college. The curricular materials for TICCIT's introductory algebra might be weaker than those that correspond to intermediate or advanced algebra. But the rates for the TICCIT program in Math 106 and Math 117 (see Table 4.2) show the same relationship between conditions. Completion does improve for the most advanced math course, however this happens for the lecture condition as well as the TICCIT program. Differences in the quality of TICCIT curricular materials across courses is not a tenable explanation. The design of the program was, after all, constant across applications.

Similarly, we can rule out idiosyncracies due to term or college. The TICCIT system was at its most unstable stage in the fall semester of 1975 compared to later terms of the demonstration period. The computer system seemed prone to crashes and the course materials in need of revision. There were vast improvements in system reliability, and courseware revision became a continuing process. Figure 4.1 traces TICCIT completion rates for Math 007 from the fall of 1974 to the fall of 1976. This two-year period spans the initial implementation of the program at Phoenix and the college's own use of the system after the cessation of our data collection for math courses. There is an increase in completion rate over time but the results for the TICCIT program still fall far short of those obtained in lecture classes.

The average completion rate for Alexandria's Algebra I is remarkably similar to that for Phoenix's Beginning Algebra. For the 1975-76 academic year the completion rates for Math 31 were 18% for TICCIT classes and 45% for lecture classes while those for Math 007 were, respectively, 14% and 49%. This similarity dismisses another plausible explanation for the Math 007 results in the fall term: the disparity in rates between conditions seems not to be a function of the specific college. The comparable results across colleges is instructive also because Phoenix followed the concept of mainline instruction with a high student-teacher ratio while Alexandria adhered to regular class sizes for all conditions (see Appendix M). So the student-teacher ratio for the TICCIT program had scant impact on completion rates.

What plausible alternatives remain for explaining differences in completion rates between conditions? The difference in our original example, Math 007 in the fall term, might be attributed to instructors. Except a student on the TICCIT system had no instructor other than TICCIT. Members of the math department shared supervisory duties for TICCIT classes by rotating according

Completion Rates Across Academic Terms

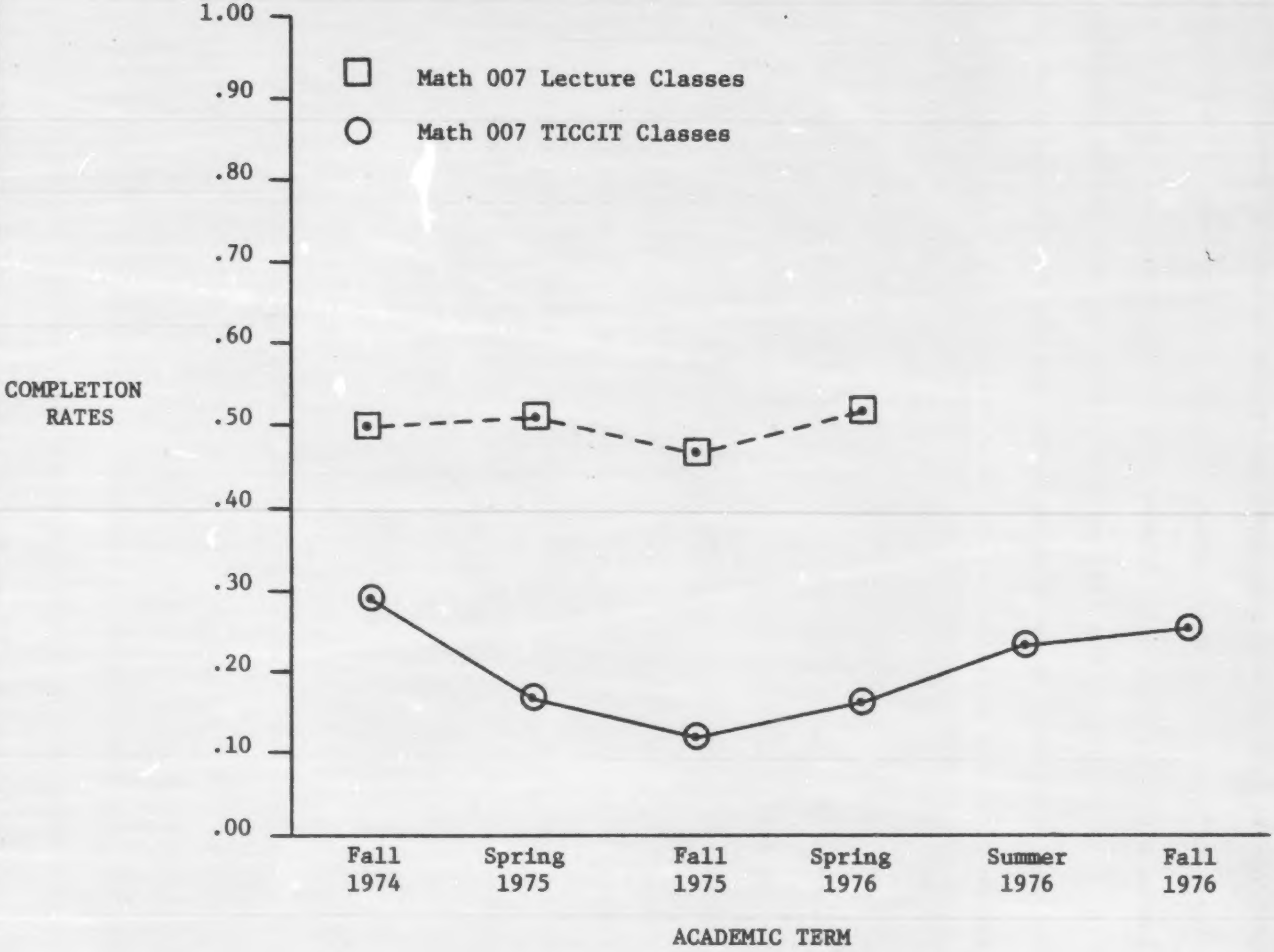

Figure 4.1

to an hourly schedule. There were no course sections as such and so there could be no effect on a student's grade due to an instructor. Half of the math department at Phoenix shared responsibility for students on the TICCIT system. Then perhaps instructors for lecture sections were overly lenient in grading, or those responsible for TICCIT classes overly stringent. The evidence to counter such arguments appears in Chapter 5: Student Achievement.

Only dissimilar student groups under each condition seems to be left as an alternative explanation. But recall that students were randomly assigned to conditions. And analyses for completion take prior ability and student background into account. The consistency of the completion figures across courses, terms and colleges is simply too high for us to entertain rival explanations. Lower completion rates were part of the TICCIT program for math. It is natural, then, to wonder what caused this effect. The question is appropriate but an answer would be premature before presenting rates from English courses and results of analyses.

At least another point of consistency in completion results should be noted for math courses. The rates for finishing a course with credit run closely together for TICCIT classes and programmed instruction throughout Alexandria's 1975-76 academic year (see Table 4.3). The audio-tutorial format for Phoenix's Beginning Algebra, abandoned after the spring of 1975, had an average completion rate of 27% for the 1972-73 academic year. Although all compare unfavorably with the completion rates found in lecture conditions, the completion results from self-paced programs appear fairly consistent between one another.

4.3.b English Courses

Tables 4.4 and 4.5 present grade distributions and completion rates for English courses at Phoenix and Alexandria. Courses from Phoenix again represent a stronger test case for the TICCIT program. A larger number of students took English courses on the TICCIT system and these courses adhered more closely to the concept of mainline computer-assisted instruction. But the applications at the two colleges were also quite different. English 019 and English 029 serve as prerequisites to the Phoenix course equivalent to college composition. These courses cover the fundamentals of English for the student weak in writing skills. In contrast, the course at Alexandria is its English Composition I. Instructors there used the TICCIT program primarily in those course sections that met five rather than the usual three periods per week. And such laboratory sections met in traditional classrooms for lecture-discussion sessions as well as working on the TICCIT system. The Alexandria application combined TICCIT with regular teaching practices and so represents the use of the TICCIT program in an adjunctive manner. The context of TICCIT's application at the two colleges is a necessary introduction to the tables on completion.

Obviously the completion rates for the TICCIT condition were higher in English courses than they had been in math. The lowest rate for a TICCIT application in an English course is higher than any attained in a math course. It seems that regardless of condition the proportion of students who receive course credit is higher for English courses. There is, still, a gap between the TICCIT and lecture conditions. But the extent of the difference is much smaller. At Phoenix fewer than twenty percentage points separate the rates for the two conditions. For Alexandria the size of the difference stays at about ten percentage points across terms.

Course Completion Rates
Phoenix
English 019 and 029
Calendar Year 1976

			Grade Distribution												
Term and Course	**Comparison Group**	**Number of Students**	**Credit (A,B,C,D)**		**Failure (F)**		**Incomplete (X)**		**Re-enroll (Z)**		**Withdraw (W)**		**Completion Rates**		
			N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**I**	**II**	**III**
Spring Semester:															
English 019	**Total**	244	113	46	1	0	11	5	42	17	77	32	.46	.68	.68
	TICCIT	88	30	34	0	0	9	10	22	25	27	31	.34	.49	.69
	Lecture	156	83	53	1	1	2	1	20	13	50	32	.53	.78	.67
English 029	**Total**	138	86	62	7	5	0	0	23	17	22	16	.62	.74	.79
	TICCIT	64	33	52	0	0	0	0	13	20	18	28	.52	.72	.72
	Lecture	74	53	72	7	9	0	0	10	14	4	5	.72	.76	.85
All Courses	**Total**	382	199	52	8	2	11	3	65	17	99	26	.52	.70	.72
	TICCIT	152	63	41	0	0	9	6	35	23	45	30	.41	.59	.70
	Lecture	230	136	59	8	3	2	1	30	13	54	23	.59	.77	.73
Summer Semester:															
English 029	**Total**	100	61	61	1	1	3	3	24	24	11	11	.61	.69	.88
	TICCIT	63	37	59	1	2	3	5	13	21	9	14	.59	.69	.84
	Lecture	37	24	65	0	0	0	0	11	30	2	5	.65	.69	.95
Fall Semester:															
English 019	**Total**	407	258	63	2	0	24	6	51	13	71	17	.63	.77	.82
	TICCIT	175	93	53	0	0	13	7	34	19	34	19	.53	.66	.80
	Lecture	232	165	71	2	1	11	5	17	7	37	16	.71	.85	.83
English 029	**Total**	216	120	56	13	6	24	11	17	8	42	19	.56	.69	.75
	TICCIT	111	54	49	3	3	24	22	2	2	28	25	.49	.65	.72
	Lecture	105	66	63	10	10	0	0	15	14	14	13	.63	.73	.77
All Courses	**Total**	623	378	61	15	2	48	8	68	11	113	18	.61	.74	.79
	TICCIT	286	147	51	3	1	37	13	36	13	62	22	.51	.66	.77
	Lecture	337	231	69	12	4	11	3	32	9	51	15	.69	.81	.81
Across Semesters:															
English 019	**Total**	651	371	57	3	0	35	5	93	14	148	23	.57	.74	.77
	TICCIT	263	123	47	0	0	22	8	56	21	61	23	.47	.61	.76
	Lecture	388	248	64	3	1	13	3	37	10	87	22	.64	.82	.77
English 029	**Total**	454	267	59	21	5	27	6	64	14	75	17	.59	.70	.79
	TICCIT	238	124	52	4	2	27	11	28	12	55	23	.52	.68	.75
	Lecture	216	143	66	17	8	0	0	36	17	20	9	.66	.73	.83
English 019 & 029	**Total**	1105	638	57	24	2	62	6	157	14	223	20	.57	.72	.78
	TICCIT	501	247	49	4	1	49	10	84	17	116	23	.49	.64	.76
	Lecture	604	391	65	20	3	13	2	73	12	107	18	.65	.79	.79

Completion Rates: I (A,B,C,D)/N II (A,B,C,D)/N-W III (A,B,C,D,X,Z)/N

Table 4.4

Course Completion Rates
Alexandria
English 111
Calendar Year 1976

			Grade Distribution												
Term and Course	Comparison Group	Number of Students	Credit (A,B,C,D)		Failure (F)		Incomplete (I)		Re-enroll (R)		Withdraw (W)		Completion Rates		
			N	%	N	%	N	%	N	%	N	%	I	II	III
Winter Quarter:															
English 111	Total	211	114	54	8	4	14	7	12	6	63	30	.54	.77	.66
	TICCIT	117	58	50	0	0	11	9	6	5	42	36	.50	.77	.64
	Lecture	94	56	60	8	9	3	3	6	6	21	22	.60	.78	.69
Spring Quarter:															
English 111	Total	339	243	72	9	3	7	2	15	4	63	19	.72	.88	.78
	TICCIT	108	70	65	2	2	4	4	12	11	19	18	.65	.79	.80
	Lecture	231	173	75	7	3	3	1	3	1	44	19	.75	.93	.77
Fall Quarter:															
English 111	Total	300	200	67	32	11	9	3	13	4	46	15	.67	.79	.74
	TICCIT	161	102	63	20	12	5	3	12	7	22	14	.63	.73	.73
	Lecture	139	98	71	12	9	4	3	1	1	24	17	.71	.85	.74
Across Quarters:															
English 111	Total	850	557	66	49	6	30	4	40	5	172	20	.66	.82	.74
	TICCIT	386	240	62	22	6	20	5	30	8	83	22	.60	.76	.73
	Lecture	464	317	68	27	6	10	2	10	2	89	19	.70	.87	.75

Completion Rates: I (A,B,C,D)/N II (A,B,C,D)/N-W III (A,B,C,D,I,R)/N

Table 4.5

Generally the withdrawal rate in English courses stayed about the same whether classes spent time on the TICCIT system or not. Hence completion rates adjusted for attrition should reflect a difference between conditions comparable to that shown by our preferred definition. The summaries for the entire year best illustrate this point. The magnitude of the difference exhibited at Phoenix across terms and courses is sixteen percentage points when we take completion as the ratio of grades with credit to total enrollment: 49% for TICCIT classes and 65% for lecture-discussion classes. It does not change the difference to adjust these rates for attrition: 64% and 79% still reflect a fifteen-point gap. For Alexandria the size of the difference also remains stable. It is ten percentage points for completion as receipt of course credit, 60% as opposed to 70%, and eleven percentage points for completion corrected for attrition, 76% contrasted with 87%. The direction of the difference always favors lecture-discussion classes.

Two exceptions occurred to completion rates otherwise unaffected by withdrawal. One was English 029, a course offered by the evening division of the College and staffed largely by part-time instructors. The other was English 111 in the winter quarter of 1976; that was the first quarter in which Alexandria had several classes on the TICCIT system and instructors were yet finding their way through the English courseware. In these cases correcting completion rates for withdrawal does narrow the difference between conditions. It becomes negligible for English 029 in the spring and summer semesters and English 111 in the winter quarter. Although these instances seem confounded with either part-time faculty practices or program novelty, they do raise the possibility that students who attend classes stand approximately the same chances for receipt of course credit under either instructional condition.

If we accept attendance as evidence of completion or assume students eventually fulfill course requirements left outstanding at the end of an academic term, it is then appropriate to turn to the third type of completion rate. Now grades of incomplete and reenroll as well as those with course credit count towards the total number of completions. And grades without penalty or credit were usually about twice as frequent in TICCIT classes as in lecture-discussion classes. We would therefore expect such a generous interpretation of completion to bring the conditions' rates closer together. It does.

Consider the complement of those courses affected by corrections for withdrawal: English 019 at Phoenix and English 111 in the spring and fall quarters at Alexandria. For the calendar year the completion rates for English 019 become 76% for TICCIT and 77% for lecture. Sections of English 111 on the TICCIT system in the spring quarter yield a slightly higher rate than lecture sections, 80% and 78% respectively. In the fall quarter there is just one percentage point separating the two conditions' outcomes.

At best, under a most lenient definition of completion, the completion rates for TICCIT and lecture classes appear comparable. But this assumes all students with grades of incomplete or reenroll eventually receive course credit. The math results suggest such an assumption is unfounded and our analyses confirm this. So, unless attendance is sufficient as a program outcome, the TICCIT program leads to lower completion rates in English courses just as it did in math.

In several cases adjusting the completion rates for withdrawals notably lessens the difference between conditions. However, these cases also involve novelty in the form of part-time instructors teaching classes or regular faculty experimenting with TICCIT use. Inconsistent grading practices seem to reflect this novelty (e.g., notice that the percentage of reenrolls doubled between the winter and spring quarters while withdrawals dropped by half) and stand as competing explanations for the lessening of differences in rates corrected for withdrawals.

On the whole it seems reasonable to conclude that in English courses as in math the TICCIT program causes a decrease in completion rates in comparison to lecture-discussion classes. Such a conclusion needs to be tested. That is the purpose of the next section of this chapter. Perhaps, though, two points should be briefly reiterated before turning to the analysis of TICCIT's impact on completion. Both concern relative completion rates among applications of the TICCIT program. The first is that the lowest completion rate for TICCIT sections of an English course was higher than any attained for the TICCIT program in a math course. The second is that the smallest difference between conditions for English courses arose with the adjunctive use of TICCIT.

4.4 Analysis of Program Effects

The purpose of our data analysis is to establish whether an apparent difference in outcomes was due to the curricular program under study and, if there were treatment effects, estimate the extent of the program's impact on student performance. Here the specific outcome of interest is course completion defined as the receipt of a final grade carrying college credit. In order to establish a difference in results as a treatment effect we must somehow isolate a program's impact and take other plausible explanations into account. Our approach to this problem was to base the evaluation on comparisons between student groups exposed to either the TICCIT program or, as a relative standard, lecture-discussion instruction. Also data were collected on probable correlates of student performance such as entrance knowledge of the subject matter and grade point average. By taking these factors into consideration and either assigning students randomly to conditions or adjusting estimates for students similar across conditions, we hoped to isolate treatment effects.

Generally the population of students that concerns us in examining completion is that which registers for a course at the beginning of an academic term. Where natural divisions exist among classes, such as day and evening or laboratory (five sessions per week) and regular (three sessions per week), these define subpopulations. Student characteristics might also define subpopulations. But we need not specify a different treatment effect for every particular group in the population. The only ones warranting separate estimates will be those for which there is evidence of a differential treatment effect. When the impact of the curricular program varies according to some independent variable, then it is appropriate to estimate effects for the subgroups defined by that variable.

It is difficult to conceive of a differential treatment effect in general terms. The most common example is probably a compensatory program that benefits some students more than others: those weakest in entrance knowledge might show the largest gains in achievement. Such a differential effect on achievement would be seen as an interaction between treatment condition and pretest in our analyses. But let us also interject an example taken from our analyses of completion in math courses. The TICCIT program in algebra required that students do nearly all their course work on the computer system. Part-time students with responsibilities at home or work might find such mainline instruction inconvenient and gradually fall behind in their studies. This is a plausible interpretation of what happened in Beginning Algebra at Phoenix. Possibly because of an inability to study outside of school, part-time students as a group had a lower completion rate than full-time students in the TICCIT program. This interaction between treatment condition and student status calls for separate estimates of treatment effects: one for part-time students and another for full-time students (see Tables 4.6 and 4.10).

Interactions of the TICCIT condition with other variables assume importance in our analysis of completion for two reasons. The first relates to their possible influence on other aspects of the evaluation, particularly the study of student achievement and attitudes. If part of TICCIT's effect on completion is to exclude or include certain student groups from the posttesting or surveying conducted at the time of course completion, there might be a systematic bias in later comparisons of achievement and attitude results. This threat to validity holds only where one condition, whether TICCIT or lecture, exerts a differential effect on completion. But aside from possible negative consequences for the evaluation there is valuable policy information to be gleaned from interactions. If a school knows which students benefit most from alternative curricular programs, it can begin to assign students to programs based on that information and perhaps begin to improve overall results. Or such interactions may suggest different and hopefully more effective applications for a new program.

For these reasons interactions will be presented as part of our analyses whenever they constitute a significant contribution to the explanation of an outcome's variance. If the t-statistic associated with an interaction surpasses a value of approximately 2.00, that interaction accounts for outcome variance left unexplained by our other independent variables and therefore becomes part of the regression analysis through a step-wise procedure. We actually tested a large number of potential interaction terms in our regressions. Some might be expected to enter the analyses by chance alone. Rather than ignore these as simply chance occurrences, however, we've chosen to present all such terms in our tables. This represents a conservative position in its explicitness about threats to validity and a liberal one in its explication of results with policy implications. So it is appropriate to exercise caution before taking any single interaction as a definitive statement for school practices. Instead only those replicated across terms and colleges should be taken as conclusive.

Of course establishing response functions with single-term independent variables always preceded our tests for differential effects (see Section 2.4, Data Analysis in Chapter 2: Methods and Measurement). The separate response functions, one for each condition, could actually be simplified to a regression model. Unless significant interactions occurred, the estimated treatment effect is given by just one term in the model. The tables that follow refer to this term as the independent variable labeled "Condition". Wherever an interaction is listed as part of the analysis, there is no single treatment effect, and several estimates corresponding to subpopulations will be presented. The dependent variable in all analyses for completion was the final course grade reduced to two values: 1 if the student received course credit (grades of A,B,C, or D in most courses and S in developmental math at Alexandria or P in special cases) and 0 if the student fails to fulfill course requirements within an academic term (grades of F,W,X or Z at Phoenix and F,W,I and R at Alexandria as well as U in developmental math).

4.4.a Math Courses

Tables in this section present the analyses for completion as a program outcome in math courses. It is naturally tempting to proceed immediately to the statistical tests but a few general remarks should be made first. Each course appears along with a simplified regression model for its completion rate. We consider each course separately, consistent with our interest in student population enrolled for a course and our use of course-specific achievement measures. Multiple courses and terms provide an opportunity to study replications of effects.

The model reported for each course and term draws on data from a student sample which is always less than the total enrollment. This is because not all students who registered for a course actually attended classes and sometimes there were exceptions to our plan of collecting data in all sections. Also as the number of variables in the vector of covariates increased, the chances of omitting a student due to a single missing value for an independent variable increased. But incomplete data, occasional disruptions in data collection and attendance do not account for the low sample size in Phoenix's Beginning Algebra for the spring semester and Alexandria's Algebra I in the winter and spring quarters. In these cases a large percentage of students simply avoided taking pretests and did so with some justification. These students had already taken the pretest in a prior term and therefore objected to a second administration when they enrolled for the same course again. At Phoenix, for example, over three-quarters of the students who reenrolled for Math 007 on the TICCIT system avoided a second pretest administration. The percentage pretested was obviously much higher for students enrolled in a course for the first time.

The number and nature of independent variables included in the analyses follow from three considerations. When students were randomly assigned to conditions (the fall semester at Phoenix), there was no need for an extensive base of covariates. The assignment procedure itself was a reasonable guarantee of student similarity across conditions. But when the evaluation relied on quasi-random assignment, like blind section selection, or on straightforward student preference, as was the case with English courses at Phoenix, there is cause to check further on student similarity. The variables in our models do not, however, represent the full set available to us (see Figure 2.7). Those omitted were found to be unrelated to completion and only further reduced sample size due to incomplete data. Indeed we might have anticipated that pretest score would override any contribution to the model's power by high school or grade point average. Such facts were established from preliminary work with data from the implementation trials and confirmed by exploratory analyses for the demonstration period. Finally, where the simple model could be significantly improved by the addition of an interaction term, that term was also included in the regression model.

The results of these analyses appear in Tables 4.6 and 4.7 for math courses at Phoenix and Alexandria, respectively. As might be expected from the data summaries on course completion, the consistency of the results across courses and terms is striking. The TICCIT program had a significant negative effect on student completion of course requirements within an academic term. This holds for all seven analyses conducted for Phoenix math courses and three of the five done for Alexandria. And there is reason to question not the ten significant cases but the two exceptions.

The regression weights given for TICCIT as the instructional condition correspond to the estimated treatment effect ($\hat{\tau}$). Thus the estimated effect of the TICCIT program on completion for Math 007 in the fall semester was -.359. This corresponds closely to the actual difference in completion rates between TICCIT and lecture classes, -.34 (see Table 4.2), calculated directly from official college rosters. Even the weight for Math 31 in the winter quarter, -.176, matches the actual difference in completion rates, -.18, very closely. And this was one of the two cases where the null hypothesis of equivalent completion rates between conditions could not be rejected.

Course Completion Rates: Analysis of Grades with Credit
Phoenix
Math 007, 106, 108, and 117
Academic Year 1975-76

Course	Math 007		Math 106		Math 108		Math 007		Math 106		Math 108		Math 117	
Term	Fall Semester		Fall Semester		Fall Semester		Spring Semester		Spring Semester		Spring Semester		Spring Semester	
Number of Students	N = 422		N = 180		N = 133		N = 282		N = 212		N = 112		N = 138	
Multiple Correlation	R = .56		R = .55		R = .54		R = .52		R = .56		R = .52		R = .53	
Independent Variables:	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition-- TICCIT(1)/Lecture (0)	-.359	-8.76***	-.155	-2.27*	-.414	-5.93***	-.615	-6.32***	-.470	-7.70***	-.413	-4.09***	-.488	-5.69***
Entrance ability-- Pretest	.016	9.05***	.022	8.18***	.014	4.45***	.014	5.95***	.035	3.94***	.013	3.31**	.031	3.03**
Division-- Day(1)/Evening(0)	-.017	-.39	.085	1.02			.078	1.01	.011	.14	.154	1.25	-.058	-.56
Student status-- Full-time(1)/Part-time(0)							-.172	-2.20*	-.080	-1.04	-.148	-1.46	-.008	-.08
Employment-- Full-time(3)/Part-time(2)/ None(1)							-.050	-1.31	-.072	-1.63	-.034	-.53	-.105	-1.54
Enrollment in course-- Repetition of course(1)/ First enrollment(0)							.065	.90	.024	.34	.074	-.72	-.152	-1.40
Maturity-- Age(Years)							.000	.10	.006	1.58	-.003	-.36	.014	1.71
Sex-- Male(1)/Female(0)							-.117	-2.14*	-.032	-.50	.043	.52	.136	1.56
Interaction-- TICCIT* student status							.289	2.43*						
Constant--	-.051		-.635		-.042		.326		.118		.084		.187	

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*p<.05
**p<.01
***p<.001

Table 4.6

Course Completion Rates: Analysis of Grades with Credit
Alexandria
Math 31 and 32
Academic Year 1975-76

Course	Math 31		Math 31		Math 32		Math 31		Math 32	
Term	Fall Quarter		Winter Quarter		Winter Quarter		Spring Quarter		Spring Quarter	
Number of Students	N = 139		N = 75		N = 39		N = 67		N = 67	
Multiple Correlation	R = .66		R = .38		R = .76		R = .40		R = .51	
Independent Variables:	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition-- TICCIT(1)/Lecture(0)	-.446	-7.07***	-.176	-1.39	-.472	-4.03***	.019	.16	-.490	-4.01***
Entrance ability-- Pretest	.013	4.62***	.011	2.15*	.024	1.27	.013	2.42*	.026	1.25
Division-- Day(1)/Evening(0)	.247	3.11**	.098	.71	-.354	-2.44*	.019	.10	-.072	-.49
Student status-- Full-time(1)/Part-time(0)	-.210	-2.80**	-.082	-.56	.174	1.10	-.152	-.79	.025	.19
Employment-- Full-time(3)/Part-time(2)/ None(1)	-.014	-.32	.081	1.02	-.151	-1.93	-.051	-.46	.083	.98
Enrollment in course-- Repetition of course(1)/ First enrollment(0)	-.096	-1.26	.116	.93	-.028	-.20	.052	.41	.225	1.84
Maturity-- Age(Years)	.001	.27	-.006	-.77	-.009	-.82	.006	.60	-.001	-.13
Sex-- Male(1)/Female(0)			-.079	-.62	.165	1.32	-.008	-.06	-.148	-1.21
Constant--	.129		.142		.645		-.128		.345	
With Programmed Instruction:	N = 183		N = 110				N = 101			
	R = .66		R = .35				R = .43			
Condition-- TICCIT(1)/Programmed(-1)/ Lecture(0)	-.141	-4.11***	-.035	-.54			-.008	-.12		
Lecture(1)/Programmed(-1)/ TICCIT(0)	.305	8.23***	.170	2.40*			-.023	-.00		

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*p<.05

**p<.01

***p<.001

Table 4.7

These estimated treatment effects represent the difference in completion rates between conditions. Put another way, the weights represent the change in a student's likelihood of completing a course with credit if he were to be assigned to the TICCIT program instead of a lecture class. A weight of -.359 corresponds to a decrease of 35.9% in a student's probability of course completion. Hence, if 50 students out of an original enrollment of 100 receive grades with credit in lecture sections, then 14 students out of every 100 enrolled for the same course on the TICCIT system would be expected to receive credit. Multiply the regression weights for instructional condition by 100 and that usually negative number gives the impact of the TICCIT program on course completion per block of 100 students enrolled in TICCIT classes. It tells how many students in one hundred would be expected to receive course credit in lecture sections but failed to do so under the TICCIT program. The lost credits if calculated this way amount to a sizable sum across courses and terms.

The clearly negative treatment impact shows despite adjustments for student traits. Entrance knowledge of the subject matter is another factor in course completion; pretest score serves as a significant covariate in each case at Phoenix and most cases at Alexandria. The estimated treatment effects, however, already incorporate adjustments made for the similarity of students across conditions. So the significance of other independent variables does not change the regression weight for instructional condition: $\hat{\tau}$ remains the same. Except where a regression model for a course also has a term indicating an interaction between condition and another variable; then $\hat{\tau}$ is a function of the regression coefficients for both the instructional condition and the interaction.

There is such an interaction listed for Math 007 in the spring semester. It necessitates separate estimates of TICCIT's effect on two subpopulations.

For part-time students the weight given for condition holds as the estimated treatment effect. But for full-time students there is another term to consider. The difference between conditions is still the sum of those weights involving the TICCIT program: -.615 for condition and .289 for condition and student status. The latter weight only applies for full-time students so $\hat{\tau}$ for that subpopulation is -.326 while -.615 holds for part-time students. This would imply greater difficulty for part-time students in completing a math course on the TICCIT system. However, it is an illustrative rather than conclusive treatment-trait interaction since it does not occur elsewhere.

There is another interaction notable for its absence. If students reenrolled for a course on the TICCIT system and succeeded in fulfilling course requirements at an improved rate, there should be a significant term involving condition and enrollment in course. No evidence was found supporting an improved completion rate among students repeating a course under the TICCIT program. Even the regression weights for student status by itself indicate only a slight advantage for students reenrolled in a course over those enrolled for the first time.

But contrary to the trend of negative results for the TICCIT program, there was no significant difference between conditions for Alexandria's Algebra I in the winter and spring quarters. Yet the overall completion rate in TICCIT classes was .24 for these two terms, and rates among lecture sections would usually reach about twice that figure. In the winter quarter the rate for lecture sections was well above that for TICCIT classes. Perhaps the sample size represents part of the explanation for no significant result. The statistical test associated with the condition variable for Math 106 in the fall semester was significant; this course had a much larger number of students and an even smaller regression weight for condition than those for

Math 31 in the winter quarter. By the spring term at Alexandria a decision had been made to discontinue the Math 31 sequence. Perhaps this decision, along with a surprising decline in the lecture completion rate through the academic year (see Table 4.3), further accounts for Alexandria's Algebra I as the exception to our otherwise significant findings. Indeed the lecture completion rate dropped to half of its fall level by the spring quarter.

While the enrollment and completion rate in lecture sections fell across quarters, enrollment increased and completion held relatively stable for Math 31 sections under programmed instruction. So the same reasons do not seem appropriate as explanations for no significant differences between the programmed and TICCIT conditions. For these contrasts two cases of the three possible tests were not significant. There was one quarter in which the completion rate under programmed instruction surpassed that for the TICCIT program. But this was the fall quarter when the computer system was at its most incomplete and unstable stage in the demonstration.

The results of comparisons between programmed and TICCIT instruction should not be interpreted as conclusive. There were only three test cases that involved both conditions. And there was a considerable amount of shifting between conditions (see Table 4.1). But the completion rates observed in TICCIT classes and programmed instruction sections, together with the historical data from audio-tutorial classes at Phoenix, do suggest comparable outcomes among self-paced programs.

4.4.b English Courses

Much of the discussion that preceded our presentation of the analyses for math courses applies to English courses as well. Again our estimates of treatment effects depend on a sample of students always less than total course enrollment. This reduced number of students can be attributed to early course withdrawals and a few isolated irregularities in data collection. Again the population that concerns us is the total student body registered for a course. But interactions between conditions and other variables will require estimates of treatment effects for subpopulations. And as before the regression weight for condition corresponds to the estimated treatment effect ($\hat{\tau}$) and represents the difference in completion rates between classes on the TICCIT system and lecture-discussion sections. The analyses for English courses, however, show a significant trait-treatment interaction more often than not and in such cases the weight for condition alone is an incomplete estimate of TICCIT's impact.

Tables 4.8 and 4.9 present the regression models for completion of English courses. Three of the five course-within-term analyses show a significant negative effect for the TICCIT program. But in two of these three cases the size of the effect is a function of a student's pretest score. There is an obvious split both in terms of the significance of TICCIT's impact and in whether the size of that effect depended on entrance ability. We turned to analyses of completion as a program outcome taken across terms in the hope that a clearer picture would emerge. Both across semesters at Phoenix and across quarters at Alexandria the value of the t-statistic associated with the TICCIT condition is significant. Now the trait-treatment interaction comes into the model for Phoenix where it had been absent and no longer enters into the Alexandria model. There is apparently no simple conclusion to be drawn about TICCIT's impact on completion in English courses.

The estimated effect ($\hat{\tau}$) for those cases in which the impact was not significant still show a negative direction. For English 019 and English 029, the day and evening versions of essentially the same course, the weight for the condition variable in the regression model is -.12 in the spring

Course Completion Rates: Analysis of Grades with Credit
Phoenix
English 19 and 29
Calendar Year 1976

Term	Spring Semester		Fall Semester		Across Semesters	
Number of Students	N = 217		N = 423		N = 640	
Multiple Correlation	R = .21		R = .30		R = .23	
Independent Variables:	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition:						
TICCIT(1)/Lecture(0)	-.121	-1.73	-.172	-3.40***	-.396	-2.99**
Entrance ability:						
Essay Pretest	-.016	-.33	.065	1.83	.042	1.49
Objective Pretest	-.001	-.13	.007	1.87	.000	.12
Division:						
Day(1)/Evening(0)	-.076	-.87	.040	.56	-.013	-.24
Term:						
Spring(1)/Fall(0)					-.020	-.48
Instructor:						
I1	.150	1.28	-.075	-.97	-.022	-.34
I2			.166	2.22*	.163	2.25*
I3					-.084	-.92
Student status:						
Full-time(1)/Part-time(0)	.008	-.11	.023	.39	.023	.49
Enrollment in course:						
Repetition of course(1)/ First enrollment(0)	-.078	-.60	-.357	-2.87**	-.229	-2.60**
Employment:						
Full-time work(3)/ Part-time(2)/None(1)	.017	.37	.004	.13	.011	.39
Maturity:						
Age(Years)	.006	1.46	.004	1.04	.004	1.50
Sex:						
Male(1)/Female(0)	-.047	-.65	.004	.10	-.001	-.02
Interaction:						
TICCIT* Objective Pretest					.011	2.01*
Constant--	.608		.316		.510	

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*p<.05

**p<.01

***p<.001

Table 4.8

Course Completion Rates: Analysis of Grades with Credit
Alexandria
English 111
Calendar Year 1976

Term	Winter Quarter		Spring Quarter		Fall Quarter		Across Quarters	
Number of Students	N = 158		N = 279		N = 231		N = 668	
Multiple Correlation	R = .44		R = .25		R = .43		R = .34	
Independent Variables:	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition:								
TICCIT(1)/Lecture(0)	-1.245	-3.56***	-.087	-1.04	-.689	-3.06**	-.140	-2.97**
Entrance ability:								
Essay Pretest	.008	.15	.073	1.68	.052	1.21	.048	1.82
Objective Pretest	.004	.51	.003	.78	-.004	-.58	.006	2.08*
Division:								
Day(1)/Evening(0)	.456	3.33***	.063	.72	-.086	-.97	.135	2.45*
Class:								
Laboratory(1)/Regular(0)	.271	2.49*	.047	.73			.108	2.04*
Term:								
Winter(1)/Fall(-1)/Spring(0)							-.091	2.49*
Spring(1)/Fall(-1)/Winter(0)							.028	1.02
Instructor:								
I1					-.011	-.10	-.152	-2.25*
I2					-.260	-1.62	-.432	-3.00**
I3					-.008	-.07	-.196	-2.10*
I4					.175	1.73	.096	.97
I5							.056	.81
I6							-.079	-.88
Student status:								
Full-time(1)/Part-time(0)	.084	.81	.066	.97	-.040	-.48	.047	1.03
Enrollment in course:								
Repetition of course(1)/ First enrollment(0)	-.026	-.21	-.253	-2.50*	-.276	-2.46*	-.189	-2.98**
Employment:								
Full-time work(3)/ Part-time(2)/None(1)	.159	3.01**	-.012	-.31	-.074	-1.57	.006	.24
Maturity:								
Age(Years)	.013	2.28*	.005	1.38	.011	2.33*	.008	3.07**
Sex:								
Male(1)/Female(0)	-.003	-.04	.009	.15	-.100	-1.72	-.030	-.83
Interaction:								
TICCIT* Objective Pretest	.032	2.74**			.021	2.57*		
TICCIT* I2					.529	2.87**	.420	2.58**
TICCIT* I6							-.413	-2.77**
Constant--	-.420		.318		.805		.170	

Table 4.9

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*$p<.05$

**$p<.01$

***$p<.001$

semester. Judging from its associated t test, such a weight would be expected to occur by chance alone in about 10% of all similar cases. It is unlikely but not significant at accepted levels. For English 111 in the spring quarter at Alexandria the estimated treatment effect is -.09. Just chance occurrences instead of treatment conditions could well account for this effect. Each of these cases involves over 200 students so neither can be faulted for small sample size. Nor is the estimated effect far different from the tabled completion rates for these or other terms (see Tables 4.4 and 4.5). Quite simply there was no significant difference between conditions for these two cases.

In the fall semester at Phoenix the completion rates were .51 for TICCIT classes and .69 for lecture-discussion sections. The estimated treatment effect is a close match to their difference: $\hat{\tau}$ is -.172. Here the difference is statistically significant ($t = -3.40$, $p < .001$). And there seems to be no basis for challenging the result. This case has the highest enrollment of any English course in any term as well as the largest number of students learning writing skills on the TICCIT system. It is true that the multiple correlation is low, .30, and the regression model therefore accounts for a scant amount of outcome variance. But the dependent variable is just a dichotomous one with values of 1 for receipt of course credit and 0 otherwise, and none of our models attains a high multiple correlation with completion (except for Math 32 in the winter quarter where the sample is very small). Still, the effect is greatly reduced from the size of those found in math courses.

Two analyses for courses within a term remain: Alexandria's English 111 in the winter and fall quarters of 1976. Both involve a trait-treatment interaction term. With such a term in the model the weight for the condition variable by itself gives an exaggerated and incorrect picture of the treatment effect. The size of a correct estimate depends on a trait as well. Here that trait is a student's entrance ability. And because entrance ability is a student's score on the objective pretest for writing skills, there is not a single estimate that describes the treatment effect. Instead a series of effects exists along the range of pretest scores.

Each estimated treatment effect is a function of the regression weights for condition and entrance ability as well as actual pretest score. Judging by the size and direction of the condition weights that appear for the winter and fall quarters of English 111 (-1.245 and -.689), there is a high negative effect associated with low pretest scores. However, if we consider the highest possible pretest score (40) along with the coefficients for the interaction terms (.032 and .021), the product of maximum score and coefficient exceeds the size of the coefficient for the condition term alone: $\hat{\tau} = -1.245 + .032(40) = .035$ and $\hat{\tau} = -.689 + .021(40) = .151$ for the winter and fall quarters, respectively. Thus, under the best circumstances, the TICCIT program might result in a slight lt positive effect on completion.

Actually there is one estimate that represents the treatment effect averaged across the entire population. Even for cases in which an interaction term enters into the regression model, we can use the average trait value to obtain an average treatment effect. Taking the weight for condition plus the product of the interaction coefficient and the mean pretest score gives the average estimated treatment effect. For the winter quarter this would be

$$\hat{\tau} = -1.245 + .032(28.71)$$

and for the fall quarter

$$\hat{\tau} = -.689 + .021(25.68).$$

If in addition we estimate the treatment effect for pretest scores about two standard deviations on either side of the mean, our estimates cover the range of actual effects well. For the winter term the average TICCIT effect is -.33 and the extreme effects -.76 and .03. For the fall term the average TICCIT effect is -.14 and the extreme effects -.47 and .17. There is evidence that student work on the TICCIT system had a differential impact on course completion. It hindered students of very low entrance ability and benefited those of very high. And this evidence is drawn from an adjunctive application of the TICCIT program.

Several points might lead us to question whether a differential treatment effect in fact occurred. There were nearly a hundred interaction terms checked for possible inclusion in our models of completion for English courses. So a few interaction terms could be expected to reach a significant level in a statistical test by chance alone. But chance would be strongly against the repetition of the same interaction term as happened in the winter and fall quarters of English 111. However, the same term does not come into the regression model for completion across quarters at Alexandria. Instead we find a number of significant terms involving instructors, which suggests instructor effects as a plausible alternative to a differential treatment effect. But the fall quarter had the best control for instructor effects and here the interaction appears in the model. Perhaps data from the spring quarter masked the differential effect in the regression model for multiple terms. Maybe the interaction is peculiar to Alexandria. But the multiple term model for Phoenix also includes pretest-condition as a trait-treatment interaction term.

We tend to believe that the TICCIT program, as implemented for the demonstration, exerts a differential effect on student completion of English courses. The effect is most pronounced for students least capable in terms of their entrance knowledge of writing skills. For these students the TICCIT program leads to fewer completions, anywhere from about twenty to over seventy fewer completions per hundred students, than the lecture-discussion completion rate would yield. At the other end of the range in pretest scores, the TICCIT program probably results in a completion rate equivalent to, or higher than, the rate for lecture-discussion classes. The data suggest that there is a relationship between objective pretest and course completion in TICCIT classes while none seems to exist in lecture-discussion sections.

Apparently students who enroll in a course again stand a poorer probability of completion than students enrolled for the first time. The statistical test associated with enrollment status is usually significant. In fact, the variable representing prior enrollment is not significant in only two cases. And these two correspond to the initial term of the demonstration period. Otherwise the percentage of reenrolled students finishing a course was about twenty points lower than the percentage of students completing a course in their first attempt. Even when we look to subsequent terms the completion rate for TICCIT classes does not improve.

4.4.c Estimated Treatment Effects

A summary of estimated treatment effects ($\hat{\tau}$) appears in Table 4.10. Of the seventeen analyses we conducted for courses within terms, thirteen indicated that the TICCIT program had a significant negative impact on course completion. All of these results referred to outcomes under lecture-discussion conditions as a relative standard for comparison and were based on our definition of completion as receipt of course credit within an academic term. So each estimated treatment effect, when negative in direction, corresponds to a loss in earned credit hours due to TICCIT. The product of 100 times an estimated effect tells us the number of students, per 100 enrolled in a course, who did not complete course requirements on the TICCIT system but

Estimated Treatment Effects on Course Completion

College	Term	Course	Effect ($\hat{\tau}$)	t-Statistic	Population
Phoenix	Fall 1975	Math 007	-.359	-8.76***	All Students
		Math 106	-.155	-2.27*	All Students
		Math 108	-.414	-5.93***	All Students
	Spring 1976	Math 007	-.326	-10.77***	Full-time Students
		Math 007	-.615	-6.32***	Part-time Students
		Math 106	-.470	-7.70***	All Students
		Math 108	-.413	-4.09***	All Students
		Math 117	-.488	-5.69***	All Students
		English 19, 29	-.121	-1.73	All Students
	Fall 1976	English 19, 29	-.172	-3.40***	All Students
Alexandria	Fall 1975	Math 31	-.446	-7.07***	All Students
	Winter 1976	Math 31	-.176	-1.39	All Students
		Math 32	-.472	-4.03***	All Students
	Spring 1976	Math 31	.019	.16	All Students
		Math 32	-.490	-4.01***	All Students
	Winter 1976	English 111	-.333	-3.50***	Dependent on Ability
	Spring 1976	English 111	-.087	-1.04	All Students
	Fall 1976	English 111	-.139	-2.33*	Dependent on Ability

*p<.05

**p<.01

***p<.001

Table 4.10

would be expected to do so under lecture conditions. Or the estimated effect can be interpreted as the change in a student's probability of completing a course if he enrolls in a TICCIT class instead of a lecture-discussion section.

Only two of twelve analyses for math courses failed to demonstrate a significant TICCIT effect. There is reason to doubt these two results since sample size was small and completion rate declined across quarters for lecture sections but held stable and low for TICCIT classes. At Phoenix where the TICCIT application was mainline in nature, the effect on completion was significant and negative in all math courses. The evidence is conclusive that the TICCIT program had a detrimental effect on student completion of math courses and, hence, on the productivity of the community colleges' math curriculum. However, this TICCIT effect is not unlike that found with other self-paced instructional programs.

The results from English courses do not suggest as strong a conclusion as those from math. A significant negative impact on completion was indicated in three of five cases. Certainly such an incidence of statistical tests significant at accepted levels of probability does not come about through chance occurrences. And those cases where the effect was significant include one with the highest enrollment among English courses and another with the most control over instructor effects in the evaluation. Yet the average effect size in English courses is half that in math courses, and the effects were less detrimental for more capable students (and even slightly positive for the most capable students). The TICCIT effect on completion of English courses is neither as strong nor as prevalent as the estimated effects for math courses. But there was a negative impact associated with the use of the TICCIT system, especially for students weak in their prior knowledge of writing skills.

4.5 Enrollment in Subsequent Terms

The primary reason behind TICCIT's negative effects on completion is evident from the grade distributions themselves. Nearly half of the grades for math courses on the TICCIT system was the one that signified effort by the student but insufficient achievement to warrant receipt of course credit (see percentage of Z grades at Phoenix and R at Alexandria in Tables 4.2 and 4.3). Students had to enroll in the course again and satisfy all course requirements in order to receive credit. But did these students reenroll for the same course? One of the original goals of the TICCIT program was to improve students' approach toward the subject matter as reflected by increased enrollments in advanced courses. Clearly the completion rates preclude such a trend. But what happened to the enrollment in subsequent terms as a result of the TICCIT program?

Here we present descriptive data on student enrollment in the term after their exposure to the TICCIT system. Because the demonstration period for English courses spanned a calendar year interrupted by a summer, the data concern subsequent term enrollment for math courses. Math courses involved a far greater percentage of grades without credit and the fixed sequence common in courses (e.g., Algebra I, Algebra II) made it easier to detect enrollment trends. Also the demonstration period for math courses offered as part of the TICCIT program covered the 1975-76 academic year, and so we expected a more natural enrollment pattern from term to term.

Exactly 50% of the students who had received a grade of reenroll in a TICCIT class registered for the same course again. Of the 268 students given a grade of Z in Math 007, 106 or 108 in the fall semester, 134 registered for the same course in the spring (see Appendix N). The course repetition rate among students given reenroll grades in lecture sections was only 18%.

At least the students at Phoenix returned in the next semester and tried to finish their course studies on the TICCIT system. For we know that there was little changing of conditions from term to term: students evidently did not wish to sacrifice what progress they had already made under one condition.

At Alexandria the percentage of students repeating a course out of those given reenroll grades varied little across conditions. It was about 20% from the fall to winter quarters and close to 50% from the winter to spring quarters. There was greater variance across quarters than across TICCIT, programmed and lecture conditions. Perhaps the college's decision to abandon the Math 31 sequence played a role in the sharp increase for the winter-spring return rate. It was the student's last chance to fulfill course requirements left outstanding from a prior term. That there is no difference in the rates across conditions should be expected.

The rates at which students elected to take a more advanced math course in a subsequent term were fairly consistent across courses, terms and colleges. Approximately 50% of the students who had received course credit in one term registered for a more advanced math course in the next term. The rates did increase from the fall-winter quarters to the winter-spring quarters at Alexandria, but probably for much the same reason that the repetition rate jumped. Admittedly differences exist between conditions as can be seen from the data breakdown in Appendix N. Sometimes these favor the TICCIT program and other times traditional practices. However, the number of students receiving credit is often so small that we should collapse across courses and terms for a more stable picture. It is then that rates for further study appear comparable across conditions. Exposure to the TICCIT program, therefore, does not seem to encourage or discourage further math study (see also Chapter 7: Student Activities for supporting data).

Collapsing the counts presented in Appendix N across grades gives another picture of what happens in student enrollment for subsequent terms. The percentage of students returning to the college, repeating a math course or electing a more advanced course appears for all students regardless of prior grades. And these totals better reflect TICCIT's overall impact on college enrollment.

Tables 4.11 and 4.12 present summaries of student enrollment from one term to the next. In Table 4.11 the last two rows of totals by condition refer to the cumulative trends across math courses. Thus 329 of the 435 students who had taken a math course on the TICCIT system in the fall semester returned to the college for the spring. Of these returning students, 147 were repeating the same math course they had taken in the previous term. Fully 34% of the students enrolled for a math course under the TICCIT program in one term repeated the same course again in the next term. Granted that almost all these students were continuing rather than repeating, the figure to us is still staggering. One of every three students who started a math course on TICCIT came back for the same course in the next term.

If the repetition rate for lecture sections were as high or if the return rate for TICCIT classes were high enough to compensate for differences in repetition, either would temper our interpretation of TICCIT's apparent impact on course repetition. But fewer than 10% of the students from lecture sections repeated the same course in a second term and the difference in return rates, 76% for TICCIT and 72% for lecture, hardly accounts for the gap in repetition. The proportion of the student enrollment from one term that elected to take more advanced math courses in the next term also shows a negative TICCIT effect, as might be expected from its lower completion rates.

Subsequent Term Enrollment: Summary across Math Courses
Phoenix
Math 007, 106, and 108
Fall to Spring Semesters, 1975-76

	Comparison Group	Number of Students Enrolled in Fall Term	Enrolled for Spring Semester		Repetition of Course		Election of Next Course in Sequence/ Advanced Course		Change to Basic or Review Course	
			N	%	N	%	N	%	N	%
Math 007	TICCIT	215	158	73	65	30	26	12	19	9
	Lecture	361	241	67	22	6	69	19	23	6
Math 106	TICCIT	144	117	81	55	38	24	17	10	7
	Lecture	163	120	74	18	11	50	31	11	7
Math 108	TICCIT	76	54	71	27	36	5	7	3	4
	Lecture	84	76	90	12	14	24	29	5	6
Totals	TICCIT	435	329	76	147	34	55	13	32	7
	Lecture	608	437	72	52	9	143	24	39	6

Table 4.11

Subsequent Term Enrollment: Summary across Quarters
Alexandria
Math 31
Fall to Winter, Winter to Spring Quarters 1975-76

	Comparison Group	Number of Students Enrolled in Base Term	Enrolled for Next Term		Repetition of Course		Election of Next Course in Sequence/ Advanced Course	
			N	%	N	%	N	%
Math 31 Fall to Winter Terms	TICCIT	116	65	56	19	16	19	16
	Programmed	44	20	45	7	16	7	16
	Lecture	79	51	65	8	10	16	20
Math 31 Winter to Spring Terms	TICCIT	118	84	71	34	29	22	19
	Programmed	46	31	67	15	33	11	24
	Lecture	51	31	61	5	10	10	20
Totals	TICCIT	234	149	64	53	23	41	18
	Programmed	90	51	57	22	24	18	20
	Lecture	130	82	63	13	10	26	20

Table 4.12

The descriptive data from Alexandria (see Table 4.12) tend to support the results from Phoenix. The totals for Math 31 over the academic year again show a comparable return rate across conditions. One course on the TICCIT system seems not to affect students' pursuit of college studies. Again the repetition rate from TICCIT classes exceeds that from lecture sections. About 10% of lecture students repeated a course in a second term, a rate close to that from Phoenix. But about one-fifth (22.6%) of students from TICCIT classes registered for the same course in two successive terms as compared to one-third (33.8%) at Phoenix. Although the difference between conditions is narrower at Alexandria, the TICCIT rate for repeated course enrollment is still more than twice that from lecture classes.

Whether one-third or one-fifth of the students exposed to a TICCIT math course in one term reenroll for that same course in a subsequent term is a moot point. Either estimate would be an unfavorable program outcome. Students who do reenroll in a course stand no better chance for completion the second time around than students enrolled in the course for the first time. From the standpoint of program productivity or the perspective of lecture results, the TICCIT rate for course repetition represents a serious weakness.

We must remember, however, that this discussion of subsequent term enrollment has drawn on descriptive data from math courses. It would be inappropriate to view the conclusions offered here as causal inferences or generalizations applicable to subjects other than math. But the conclusions do rest on data gathered during the demonstration period of the TICCIT project and reflect what happened in applications of the TICCIT system for mainline instruction in math. Further, the stability of TICCIT completion rates over time suggests that these results on course repetition also hold over time. In explaining or arguing the validity of these descriptive data on subsequent term enrollment we should turn to the summary for Alexandria: the proportion of students who took the same course twice is comparable in the programmed instruction and TICCIT conditions.

4.6 Discussion

Any college program that results in a higher percentage of students taking a course a second time than completing it within one academic term must be said to be deficient in this aspect of student performance. The TICCIT program had a completion rate of 16% across math courses in the fall semester of 1975 at Phoenix. And 34% of the students enrolled for a TICCIT math class in the fall registered for the same course in the spring semester. Comparable rates for lecture sections were about 50% for course completion and about 10% for course repetition. The results at Alexandria were less dramatic but consistent. The TICCIT program had a definite negative effect on completion rates in math courses.

Completion rates in English courses were less affected by study on the TICCIT system. The difference in outcomes from TICCIT and lecture-discussion sections was, on the average, smaller than that typical for math courses. Still, there was a negative TICCIT effect since statistical tests were significant more often than not. And the nature of that effect was quite different in English. It appears that the TICCIT effect on course completion varied depending on a student's entrance knowledge of writing skills. With TICCIT rather than lecture-discussion alone, students weakest in entrance ability stood a much poorer probability of course completion while those students strongest had a slightly higher probability of course completion.

To what should we attribute these results? It is common for developers to counter negative findings with qualifications about the status of their product at the time of its evaluation. Certainly such qualifications bear on the validity of an evaluation. System reliability or an incomplete curricular program might account for our negative findings. But the completion results were consistent across academic terms as the TICCIT computer system reached a high reliability in its college operations. Results too were consistent across courses, so faults at just particular points in the TICCIT curriculum seems an inadequate explanation for the negative effects. Quality of the program might be cited as the reason underlying our results. Although we cannot refute such a general claim, we believe the reasons lay elsewhere.

There is a pattern to the TICCIT results that invites another explanation. The negative TICCIT effect on course completion rates was most pronounced in cases of mainline instruction and least evident in cases of an adjunctive application. This suggests extent of exposure to the TICCIT program as a plausible explanation for TICCIT effects: greater exposure leads to poorer completion rates. But the amount of time students spent on the TICCIT system contradicts such an explanation. Actually, the average number of hours per student is nearly the same in an adjunctive and mainline application of the TICCIT system (see Chapter 7: Student Activities).

In a recent review Robin (1976) noted high withdrawal rates as a persistent problem with another form of self-paced instruction for college teaching. Perhaps high withdrawal rates also affected our findings. But the percentage of such grades was lower in TICCIT classes than lecture sections for those courses where the TICCIT program had the most negative effects on completion. Obviously the cause of the TICCIT effects was not attrition: students tended to remain in their classes and simply failed to fulfill the requirements for receipt of a grade with course credit.

As independent evaluators we can take advantage of both data and hindsight. It then becomes much easier to interpret results in perspective and set forth plausible explanations. And in retrospect it seems that the reasons behind the significant TICCIT effects on completion come from the fundamental concepts of the program.

The TICCIT program led to completion rates in math courses significantly lower than those obtained under lecture conditions, but similar to those reached by other self-paced systems. Both the audio-tutorial system that preceded TICCIT at Phoenix and the programmed instruction that competed with TICCIT at Alexandria [illegible]ted in lower completion rates than lecture classes. With the outcomes of programmed instruction as a relative standard for comparison, there were generally no significant TICCIT effects on student completion or even repetition of a course. The major factor behind the TICCIT effect on course completion is probably a generic one: Programs that allow each student to proceed at his or her own pace risk loosing students unable to manage their own instruction.

The self-paced nature of the TICCIT program does not fully account for the results. A sizable percentage of students, perhaps a fourth of those who attend classes but make slow progress toward course completion, devote a substantial amount of time and effort to their TICCIT studies. Yet time on the TICCIT system seems unrelated to any external measure, such as pretest or posttest, and correlates strongly only with the number of TICCIT lessons passed by a student (see Chapter 7: Student Activities). Time alone neither guarantees completion nor compensates for weaknesses in entrance ability.

We might go so far as to question one of the initial premises of the TICCIT project: Do community college students constitute an appropriate audience for the TICCIT program? The community college, like other sectors of education, doubtless has use for effective curricula in the basic skills such as algebra and writing. Enrollment at community colleges continues to grow even as it declines elsewhere. It is an appropriate target for a market success. But the diversity of students at community colleges also makes it difficult for any curriculum to anticipate and satisfy the range of student abilities and needs. The differential TICCIT effects on student completion of English courses lend support to this view, as do student reactions to their TICCIT classes (see Chapter 6: Student Attitudes). Perhaps with a less heterogeneous group the outcomes of the TICCIT program would improve with regard to course completion. And with a homogeneous population, the TICCIT program might take advantage of management techniques known to be successful with other forms of self-paced instruction. For example, monitoring attendance and providing explicit incentives for steady course progress (Morris, Surber & Bijou, 1978) may help motivate students responsible for their own learning and thereby improve completion rates.

Finally, the pattern of the TICCIT effects leads us to comment on another aspect of the program. Its developers initially advocated use of the TICCIT system for mainline instruction. The computer was to assume primary responsibility for student instruction with the teacher available for support. Yet completion rates were lowest in TICCIT's mainline applications where the computer system directed student learning. Where the subject lent itself to active teacher participation in the instructional process (i.e., reviewing student essays and discussing themes), the gap in completion rates between TICCIT and lecture conditions closed. Where instructors assumed primary responsibility for teaching and chose to use the TICCIT system as an adjunctive resource, the average TICCIT effect was below that for mainline applications and even became positive for a select group of students.

Supporting active teacher participation in applications of instructional technology is perhaps too familiar and worn by frequent use. But the results of the evaluation of course completion as a program outcome would lead us to prefer a class in which teacher and computer share the burden of student instruction over one in which a computer system directs student learning. As we perfect our understanding of what facilitates learning and how technology best contributes to this process, it is best to draw on the experience and knowledge of teachers.

Our data show that the mainline application of the TICCIT program had a negative impact on course completion rates at community colleges. Further, there was evidence of a differential TICCIT effect on completion rates in English courses. Such findings suggest the possibility of a systematic influence on other comparisons of outcomes dependent on course completion. The evaluation of student achievement may be particularly susceptible to this threat to validity. The next chapter in our report addresses this matter further.

Chapter 5

Student Achievement

How does student achievement under the TICCIT program compare with that of students taught by conventional practices? That is the basic question addressed in this chapter. It is not so straightforward a question that the process for finding an answer is immediately evident. The question itself does imply comparing achievement results from classes on the TICCIT system and results already attainable through existing practices. It also requires unbiased measures of achievement for gathering the relevant data. Then analyses must compensate for nonequivalent comparison groups, especially since there were pronounced treatment effects on completion, by making adjustments for entrance ability and other student characteristics. Through tests prepared for this evaluation and the approach adopted for data analysis (see Chapter 2: Methods and Measurement), we can estimate what the TICCIT effects on student achievement were within the context of this demonstration.

This chapter portrays the achievement outcomes of the TICCIT program in relation to those of usual classroom teaching methods. Data pertinent to achievement as a function of unique TICCIT attributes, such as time spent on the computer system, appear elsewhere (see Chapter 7: Student Activities). The first section here deals with the measures that define achievement for our evaluation and the students within the groups on which our comparisons of program results depend. The chapter's second section presents summaries of achievement data similar to those already given for course completion; it gives descriptive statistics on pretest and posttest scores by instructional condition for each course. In the next section we turn to the analyses and estimate the actual TICCIT effects on achievement. These analyses pertain to student performance on the overall posttests for math and English courses as well as on special tests designed to assess other aspects of achievement. The fourth and final section of this chapter is a discussion of the findings and their implications.

5.1 Achievement and Students

This evaluation treats achievement as one aspect of student performance, albeit the most important one foreseen in our original plans. Because a program's impact on achievement often determines its success in schools, the tests that operationally define achievement should be fair and comprehensive. The measures prepared for evaluating the TICCIT program seem to exhibit satisfactory validity and reliability (see Chapter 2: Methods and Measurement). This is a necessary condition for making comparisons of program results, but it is not in itself sufficient for understanding our estimated TICCIT effects on achievement.

Our estimates of TICCIT's impact on achievement obviously depend on the tests given as measures of achievement and the students who took those tests. A difference between TICCIT classes and lecture-discussion sections in their achievement results will appear as a number of points on a test. Such a point difference between program outcomes may seem to be an abstract form for reporting results. So we also tried to isolate those effects reflected in posttests and checked for effects on learning at other points in a course. Still, every TICCIT effect on achievement might be suspect. Only a select group of students completed math courses on the TICCIT system and there was evidence of a trait-treatment interaction for student completion of English courses (see Chapter 4: Course Completion Rates).

5.1.a Measures of Achievement

Each estimated effect reflects the relative gain (or loss) in achievement for a student who completed a course under the TICCIT program instead of in a regular lecture-discussion section. Primarily these estimates refer to achievement as measured by our posttests. An effect of about four points, for example, would represent a difference in program outcomes of nearly ten percent in terms of total possible score on a posttest. The effects reported for achievement will be much more subtle than those for completion. They neither approach the size nor carry the direct implications of treatment effects on course completion. Instead they represent a point difference on posttests.

Although a treatment effect does not necessarily correspond to particular posttest items, it might be attributed to certain types of items and thus provide us with more specific information about the relative strengths and weaknesses of the TICCIT program. For math courses we will examine student achievement in terms of subscores for ability levels and content categories as well as total posttest scores on all common objectives (see Figure 2.3). For example, subscores for solving routine problems and demonstrating comprehension of concepts might reveal TICCIT's merits for teaching a certain type of cognitive activity, while others for arithmetic operations and linear equations might define the program's strongest points along a dimension representing the content domain. Within English courses subscores along dimensions for ability and content would contribute less to understanding TICCIT's impact than would direct tests of both writing skills and actual written work. We will report achievement differences in English courses in relation to both our objective test of writing skills and essay test. Such detailed analyses of program outcomes should permit not only summative estimates of TICCIT's effects on achievement but also specific and constructive evaluative findings for strengthening the results of subsequent TICCIT applications.

Further implications for instructional applications of the TICCIT program might be derived from measures of student achievement other than those taken at the end of a course. Posttests or final examinations reflect cumulative learning over an entire course of study. It may be the case that results in terms of the acquisition or retention of material, taken immediately upon completing a unit of study or when starting a later course in a sequence, differ from those obtained by posttesting alone. Given the modular design of the TICCIT curriculum for precalculus mathematics, students might acquire the rules and concepts for a unit of material and forget some of that learning by the end of a course. Then topical testing for immediate learning would reveal a different pattern of effects than posttesting for cumulative learning. Or the opportunity for self-paced learning and repetition on the TICCIT system might lead to overpractice and, hence, improved retention of the material covered in a course. If that material serves as a prerequisite to more advanced courses, testing for retention at the beginning of a later academic term would provide evidence of an achievement effect apart from that represented by posttesting.

The measures that define achievement for our evaluation should be sufficient for detecting overall effects, isolating the nature of these effects, and checking for effects at different stages of learning. All of these effects will be reported as point differences on special tests prepared for the evaluation. Each point difference represents a real difference in student performance. It may be helpful to consider other facts in interpreting these effects: test characteristics and sample items (Chapter 2); test coverage (Appendices C, D and E); maximum possible scores and average observed scores (Appendices O and P); and certainly the context of the demonstration (Chapter 3). But perhaps the most critical factor to consider is the population of students who took a particular test.

5.1.b Populations of Students

One of the key assumptions made in our data analyses is that there is a population from which the students may be regarded as representative. Those students who took posttests do not represent all students at the community colleges or even students enrolled for algebra and composition courses. Instead, they were the population of students who both enrolled for and received a passing grade in a target course. Had there been no treatment effects on course completion, the students completing a course under the TICCIT program and those completing the same course in lecture-discussion classes would be regarded as representative of the same population. However, the TICCIT program did affect course completion rates.

Course completion rates were generally lower in TICCIT classes than in lecture-discussion sections: fewer students received a passing grade for a course on the TICCIT system than would be expected if the same students had taken the course under lecture-discussion conditions. The population of students posttested in the TICCIT condition, therefore, is not equivalent to that posttested in the lecture condition. Although similar student populations had started courses under both conditions, a smaller percentage of students actually completed courses under the TICCIT program.

It is important to recognize exactly the intuitive approach behind our data analyses. The treatment effects on achievement represent the point difference between the actual posttest score for a student exposed to TICCIT and an estimated posttest score for that same student had he or she instead been in a lecture section. The reverse of this procedure would be to estimate what the score would be under the TICCIT program for each student completing a lecture class. But such a reversal would be inappropriate: not all students completing lecture classes would be expected to complete the same course under the TICCIT program. The treatment effects reported for posttest achievement rely on actual observed scores under the TICCIT program. There would be little value in estimating effects for students had they been able to complete a course when there were no representatives of this population.

This leaves us with achievement results applicable only to the student population capable of completing courses on the TICCIT system. For English courses such a population has considerable overlap with its counterpart under lecture-discussion conditions. The TICCIT effects on student completion of English courses were not so pronounced as to preclude comparisons of achievement. The effects on completion did vary according to prior knowledge of writing skills. But this trait-treatment interaction seems to be a separate fact: our estimates for achievement effects apply only to those students who completed English courses with TICCIT, and similar students did complete English courses under conventional classroom conditions. There was, then, a sound basis for comparing program results.

The situation for student achievement in math courses, where there were pronounced treatment effects on course completion, is different. The estimated effects on math achievement refer to about one-fifth of the population that might enroll for precalculus courses. That corresponds to the completion rate among students starting a math course under the TICCIT program. Quite simply, the outcomes of the TICCIT program with regard to course completion prevent generalizations beyond this limited population for other aspects of student performance. But pilot trials for our instruments and procedures had given us advance warning of this problem, and in one math course arrangements were made to administer posttests to all students still attending classes at the end of an academic term regardless of their anticipated grades. The population of students attending TICCIT classes through the end of a term is much larger than the one completing TICCIT classes; it is about seven-tenths of the original course enrollment. Also, topical testing for immediate learning took place earlier in a course than posttesting, and so these results bear on a broader population of students.

This has been a protracted and perhaps laborious introduction to the achievement results. But the measures that define achievement should be kept in mind while interpreting effects. And the population for which the achievement results may be regarded as representative certainly must influence any inferences made from the data.

5.2 Presentation of Results

Descriptive statistics for pretests and posttests within each class appear in Appendix O. These summaries report the number of observations per class, the mean score according to these observations, and a test's standard deviation within each class. They also present course totals for all classes within an academic term and subtotals by condition (i.e., TICCIT, lecture, programmed). This later level of achievement summary, by course within a term and broken down by conditions, is much easier to grasp and portray, and so it is the form followed in our tables (see Tables 5.1 through 5.4). Still, there is evidence in the summaries by individual classes absent in those for courses and conditions.

Perhaps the most noticeable point from the class summaries given in Appendix O is the sporadic absence of pretest or posttest data. There were occasional classes in which no pretest or no posttest data were collected. Such cases typically involved part-time instructors unfamiliar with the evaluation or English faculty members reluctant to administer an objective test of writing skills. These disruptions to otherwise smooth procedures for data collection were quite infrequent during the demonstration period of the project and seldom affected data collection within the TICCIT condition. It may seem as though several TICCIT classes of Algebra I at Alexandria neglected posttesting, but actually few of these students completed the course. Even when a difficulty occurred, there were sufficient data from other lecture-discussion classes. It is our belief that disruptions in collecting data were too infrequent to present any real threat to the validity of the evaluation.

Yet there was one case in which an irregularity with test administration prompted us to abandon further analyses. One summer term had only one lecture counterpart to three TICCIT classes for a course on the fundamentals of written English. Students in that lecture-discussion section were given inadequate time for completing the objective and essay posttests and so did poorly on those achievement measures (see p. 178 of Appendices). Thus, there was no relative standard for us to use in making fair comparisons of achievement results within the summer term. Data from other terms would be inappropriate since the summer is a special case with its own idiosyncracies. However, it should be noted that the performance of students in summer classes on the TICCIT system was consistent with results from other terms on the objective test of writing skills, better than results from other terms on the essay test, and certainly well above the performance of that summer's lecture-discussion class on both tests.

Another point concerns math courses offered after the initial academic term of the demonstration period. Often students failed to complete course requirements within one academic term and enrolled for the same course again in the next term. These students typically had taken their course's pretest once and tended to avoid doing so a second time. Thus, some students had a pretest from one academic term and a posttest from another, later term. It was important that we retain these data since completion rates severely limited the number of pretest-posttest observations. Therefore, whenever a student had a pretest and posttest taken in successive terms and remained in the same instructional condition for both terms, that earlier pretest stood as our measure of entrance ability. There were 51 such cases in the evaluation (as documented in footnotes within Appendix O).

Finally, presenting achievement results at the course level omits much of the tone of the data evident among classes. Although the average pretest score was similar across conditions, a full standard deviation frequently separated the highest class average from the lowest of the same condition. Similarly, there were differences in the average posttest score among classes of the same condition. On both the pretest and posttest, the scores of students completing a course with TICCIT usually formed the highest average for a single class. And in several cases, TICCIT classes had not only the highest mean score on the posttest but also the least variance in scores within a class. Such consistent, high performance might be attributed to mastery of the subject matter or to restriction in the range of scores due to completion rates.

5.2.a Math Courses

Tables 5.1 and 5.2 present the achievement results for math courses. As should be obvious from their respective numbers of observations, all pretests encompass a larger student population than all posttests do. The descriptive statistics for all pretests represent the entrance ability of students starting a course while parallel data for all posttests reflect the final achievement of just those students completing a course. By repeating the descriptive test data for students with both a pretest and posttest, the tables give pretest means and standard deviations for just those students completing a course. Thus, pretest-posttest observations refer to a student population different from the one which began a course but essentially the same as that which completed a course: the test data change for the pretest but stay the same for the posttest. For example, students in Math 007 for the fall semester of 1975 had a mean pretest score of 37.26 and a mean posttest score of 39.42. Among students with both a pretest and a posttest, the respective means were 41.80 and 39.32, essentially unchanged on the posttest but much higher on the pretest.

The average pretest score for students completing a course was nearly always higher than that for all students starting a course. This fact is especially apparent within the TICCIT condition. Students completing a math course under the TICCIT program often had a pretest mean approximately one standard deviation higher than that of all students who originally started the course. For lecture sections the corresponding increase was seldom one-third as large. Those students who completed a course on the TICCIT system certainly represent a more select population than their counterparts from lecture sections. Our achievement analyses deal only with pretest-posttest observations and yield estimates of treatment effects applicable only to that population of students who completed math courses under the TICCIT program.

Achievement Summary
Phoenix
Math 007, 106, 108 and 117
Academic Year 1975-76

			All Pretests			All Posttests			Pretest-Posttest Observations: Pretest			Pretest-Posttest Observations: Posttest		
Course	Term	Comparison Group	N	Mean	sd	N	Mean	sd	N	Mean	sd	N	Mean	sd
Math 007	Fall	Total	415	37.26	11.4	182	39.42	10.1	152	41.80	10.8	152	39.32	9.8
		TICCIT	161	35.32	10.2	27	44.26	6.7	22	44.86	7.8	22	43.32	6.6
		TICCIT (day)	122	35.54	10.2	19	43.21	7.5	17	43.88	7.5	17	42.00	7.0
		TICCIT (eve.)	39	34.62	10.1	8	46.75	3.6	5	48.20	8.9	5	47.80	1.9
		Lecture	254	38.49	11.9	155	38.58	10.4	130	41.28	11.2	130	38.64	10.2
		Lecture (day)	164	36.26	11.4	111	39.59	10.5	91	40.10	10.9	91	39.96	9.9
		Lecture (eve.)	90	42.54	11.6	44	36.02	9.7	39	44.05	11.3	39	35.56	10.0
		Day	286	35.95	11.0	130	40.12	10.2	108	48.20	7.9	108	40.28	9.5
		Evening	129	40.15	11.7	52	37.67	9.8	44	44.52	11.1	44	36.96	10.2
	Spring	Total	332	36.24	11.3	181	38.96	8.3	172	39.05	10.7	172	38.78	8.4
		TICCIT	110	36.15	11.4	35	40.57	6.9	32	40.06	10.5	32	40.09	7.1
		TICCIT (day)	83	36.23	10.8	30	40.03	6.9	28	39.21	9.8	28	39.64	7.1
		TICCIT (eve.)	27	35.93	13.4	5	43.80	7.3	4	46.00	16.4	4	43.25	8.3
		Lecture	222	36.28	11.2	146	38.58	8.5	140	38.82	10.8	140	38.49	8.6
		Lecture (day)	134	35.97	10.9	87	39.37	7.9	83	38.19	10.1	83	39.29	8.0
		Lecture (eve.)	88	36.76	11.6	59	37.41	9.3	57	39.74	11.5	57	37.32	9.4
		Day	217	36.07	10.9	117	39.54	7.6	111	38.45	10.0	111	39.38	7.7
		Evening	115	36.57	12.0	64	37.90	9.2	61	40.15	11.8	61	37.70	9.4
Math 106	Fall	Total	178	46.88	11.3	101	32.38	7.3	71	53.89	8.4	71	33.86	5.8
		TICCIT	98	47.14	11.7	34	36.41	4.6	29	57.00	6.4	29	35.97	4.3
		Lecture	80	46.56	10.8	67	30.33	7.6	42	51.74	9.0	42	32.40	6.3
	Spring	Total	229	13.61	3.4	108	32.64	8.5	91	14.59	3.2	91	32.09	8.7
		TICCIT	80	13.20	3.4	17	35.29	6.5	5	16.40	3.4	5	36.60	5.7
		Lecture	149	13.83	3.4	91	32.14	8.7	86	14.49	3.2	86	31.83	8.8
Math 108	Fall	Total	133	41.68	11.3	54	37.43	8.6	47	46.60	9.9	47	37.60	8.9
		TICCIT	61	44.72	11.1	10	40.50	7.6	7	51.86	8.5	7	42.29	6.8
		Lecture	72	41.68	11.3	44	36.73	8.7	40	45.68	10.0	40	36.78	9.0
	Spring	Total	153	42.52	10.9	55	39.55	8.2	52	45.15	9.6	52	38.96	7.9
		TICCIT	52	43.60	9.8	12	39.25	8.3	12	46.50	9.9	12	38.42	7.3
		Lecture	101	41.97	11.3	43	39.63	8.3	40	44.75	9.5	40	39.12	8.1
Math 117	Spring	Total	150	12.39	3.7	71	24.58	8.8	64	13.25	3.6	64	25.34	8.6
		TICCIT	43	13.02	3.5	14	24.71	7.7	12	14.33	1.9	12	25.58	7.1
		Lecture	107	12.13	3.8	57	24.54	9.2	52	13.00	3.9	52	25.29	9.0

Table 5.1

Achievement Summary
Alexandria
Math 31 and 32
Academic Year 1975-76

									Pretest-Posttest Observations					
			All Pretests			All Posttests			Pretest			Posttest		
Course	Term	Comparison Group	N	Mean	sd	N	Mean	sd	N	Mean	sd	N	Mean	sd
Math 31	Fall	Total	195	31.72	10.5	58	38.90	6.1	52	38.19	10.6	52	39.27	6.8
		TICCIT	90	31.56	11.3	9	45.33	6.2	9	47.22	10.9	9	45.33	6.2
		Programmed	47	29.74	8.5	7	34.86	6.1	4	36.50	14.8	4	34.75	7.9
		Lecture	58	33.59	10.3	42	38.19	5.9	39	36.28	9.2	39	38.33	6.1
	Winter	Total	105	30.00	12.0	62	38.53	6.6	46	34.09	9.8	46	39.07	6.6
		TICCIT	41	27.29	10.8	25	40.00	7.6	21	34.33	10.0	21	40.86	6.8
		Programmed	33	32.21	12.6	16	38.56	5.8	10	34.00	11.0	10	39.10	6.8
		Lecture	31	31.23	11.8	21	36.76	5.8	15	33.80	9.7	15	36.53	6.0
	Spring	Total	130	29.01	12.0	38	38.83	8.9	32	38.37	13.2	32	38.56	9.5
		TICCIT	41	30.12	11.9	11	40.36	8.0	9	41.33	14.1	9	40.56	8.7
		Programmed	58	26.14	10.4	16	36.44	10.7	14	33.21	12.8	14	35.79	11.3
		Lecture	31	32.90	13.5	11	40.73	6.6	9	43.33	12.2	9	40.89	7.4
Math 32	Winter	Total	44	13.84	3.4	15	20.67	5.1	14	14.29	3.2	14	20.93	5.2
		TICCIT	20	13.85	3.5	2	21.00	5.7	1	11.00	—	1	25.00	—
		Lecture	24	13.83	3.4	13	20.62	5.3	13	14.54	3.2	13	20.62	5.3
	Spring	Total	74	14.70	2.9	32	19.94	6.4	30	14.80	2.9	30	19.83	6.4
		TICCIT	34	15.32	3.1	6	25.67	8.0	6	17.50	1.8	6	25.67	8.0
		Lecture	40	14.17	2.6	26	18.62	5.3	24	14.12	2.8	24	18.37	5.3

Table 5.2

Another point evident from the summaries of achievement data is the superior posttest performance of students under the TICCIT condition. The average posttest score for students in the TICCIT program was at least one-half of a standard deviation higher than the average posttest score of students in lecture sections. This difference held across courses in the fall term but occurred in fewer courses in subsequent terms: half of a standard deviation separated the conditions during the fall term for Math 007 and 108 at Phoenix and Math 31 at Alexandria, but the mean posttest scores for TICCIT and lecture classes were much closer in the spring term for these three courses. The apparent inconsistency of achievement results across terms suggests a relevant question: Why was there a pronounced difference in posttest performance in the fall term and not in later terms?

Pretest scores probably contributed to the observed differences in posttest performance. Larger differences in the mean pretest scores of students completing a course tend to be associated with larger differences in posttest performance between conditions. In Beginning Algebra at Phoenix, for example, the fall pretest means for students completing either the TICCIT program or lecture instruction were 44.86 and 41.28, respectively. The corresponding spring pretest means were 40.06 and 38.82. There was less of a difference between conditions in terms of both pretest and posttest performance in the spring term. And the notable decrease in the mean pretest score for the TICCIT condition, 44.86 in the fall to 40.06 in the spring, is explained by the pretest scores of 13 students. There were 13 students who had completed Math 007 with TICCIT in the spring semester after starting the course in the fall; their mean pretest score from the fall was 33.92, nearly one standard deviation below that of students completing a math course on TICCIT within one term. By contrast, just eight of the 140 pretest-posttest observations for the lecture condition represented students repeating Math 007; their mean pretest score from the fall was 34.62. It seems reasonable to conclude that students who took longer than one academic term to complete their course studies affected the descriptive test statistics for later terms in the evaluation, especially within the TICCIT condition where such students constituted from one-fourth to one-half of the total number of students completing a course in later terms.

There were exceptions to the general pattern of results across terms. The spring achievement data for Math 106 still indicate a sizeable gap in posttest performance by condition, and nearly two-thirds of a standard deviation separate the conditions' pretest means in both semesters. The explanation is simply that the pretest for Math 106 in the spring was different from the one administered in the fall; the spring pretest was to serve as both a measure of retention for students who had taken Math 007 in the fall and elected Math 106 as the next course in an algebra sequence as well as a measure of entrance ability. This change in pretest forms precluded taking an earlier pretest as a match for a later posttest: all pretest-posttest observations had to be taken from within the spring semester. This also led to a poor percentage of posttest observations paired with pretests in the TICCIT condition (29%).

At Alexandria ten students who completed Math 31 under the TICCIT program in the winter quarter had actually started the course and taken pretests in the fall. Again there was a marked decrease in the mean pretest score for students completing the course under the TICCIT condition, from 47.22 in the fall to 34.33 in the winter. Unlike other cases and despite the similarity of pretest scores across conditions, the posttest means for Math 31 in the winter quarter still reflect an advantage for students completing the course with TICCIT. Posttest performance for Math 31 in the spring quarter was comparable in the TICCIT and lecture conditions, as was pretest performance. It is difficult to discern any pattern in the achievement results for TICCIT in relation to programmed instruction since there were so few observations.

Closer inspection of the achievement data can reveal further interesting features of the results. For example, the mean pretest scores of students starting a course at Phoenix varied little according to condition. Perhaps pretest means across conditions were even closer in the spring semester than the fall. Yet students chose their own classes in the spring while they had been randomly assigned to conditions in the fall. At least in terms of entrance ability, student selection and random assignment were equivalent methods for forming comparison groups.

But the central issue suggested by the achievement data is whether entrance ability accounts for the higher posttest performance observed under the TICCIT program. Analyses for the math achievement results should provide an answer.

5.2.b English Courses

Summaries of achievement data from English courses appear in Tables 5.3 and 5.4. These tables follow the same format as earlier math summaries, except they present descriptive statistics for two types of tests. The pretests and posttests given in English courses included both an objective test of writing skills and an essay test. Again the data for all pretests refer to the student population which started a course. The information for all posttests reflects the performance of those students who completed a course. Descriptive test statistics for pretest-posttest observations also represent the performance of those students who completed a course, and thus give pretest data for just those students rather than the entire student population that started a course.

Achievement Summary
Phoenix
English 19 and 29
Calendar Year 1976

Objective Test of Writing Skills								Pretest-Posttest Observations					
		All Pretests			All Posttests			Pretest			Posttest		
Term	Comparison Group	N	Mean	sd	N	Mean	sd	N	Mean	sd	N	Mean	sd
Spring	Total	283	23.17	7.4	147	26.39	6.2	131	24.49	6.6	131	26.73	6.0
	TICCIT	126	21.87	7.5	49	27.94	5.4	47	24.30	6.3	47	27.81	5.4
	TICCIT (19)	72	21.75	7.1	21	26.67	4.3	21	23.38	6.3	21	26.67	4.3
	TICCIT (29)	54	22.02	8.0	28	28.89	6.1	26	25.04	6.4	26	28.73	6.1
	Lecture	157	24.22	7.2	98	25.61	6.4	84	24.60	6.7	84	26.12	6.3
	Lecture (19)	93	24.19	6.8	68	24.50	6.3	54	23.46	6.9	54	25.00	6.3
	Lecture (29)	64	24.27	7.6	30	28.13	5.8	30	26.63	5.9	30	28.13	5.8
	Day (19)	165	23.13	7.0	89	25.01	6.0	75	23.44	6.7	75	25.47	5.9
	Evening (29)	118	23.24	7.9	58	28.50	5.9	56	25.89	6.1	56	28.41	5.9
Fall	Total	479	22.89	7.9	318	26.31	6.2	276	23.62	7.4	276	26.26	6.1
	TICCIT	182	23.99	7.9	123	27.45	6.0	87	25.37	7.3	87	27.53	5.9
	TICCIT (19)	117	21.82	8.0	82	27.63	5.1	59	24.36	7.7	59	27.64	5.4
	TICCIT (29)	65	27.91	5.9	41	27.07	7.6	28	27.50	6.1	28	27.29	7.0
	Lecture	297	22.22	7.9	195	25.60	6.2	189	22.82	7.3	189	25.67	6.1
	Lecture (19)	210	21.00	7.5	149	25.08	6.1	145	22.14	6.8	145	25.25	6.0
	Lecture (29)	87	25.17	8.1	46	27.28	6.4	44	25.05	8.3	44	27.07	6.5
	Day (19)	327	21.29	7.7	231	25.99	5.9	204	22.78	7.2	204	25.94	5.9
	Evening (29)	152	26.34	7.4	37	27.18	7.0	72	26.00	7.6	72	27.15	6.7
Essay Tests													
Spring	Total	300	2.02	.8	145	2.14	.8	137	2.08	.8	137	2.14	.8
	TICCIT	124	1.96	.8	49	2.26	.7	47	2.10	.8	47	2.26	.7
	TICCIT (19)	72	1.85	.7	21	2.36	.7	21	1.74	.6	21	2.36	.7
	TICCIT (29)	52	2.11	.8	28	2.18	.7	26	2.38	.8	26	2.17	.7
	Lecture	176	2.07	.8	96	2.08	.8	90	2.08	.8	90	2.08	.8
	Lecture (19)	115	2.03	.8	66	2.14	.8	62	1.98	.8	62	2.15	.8
	Lecture (29)	61	2.14	.7	30	1.95	.7	28	2.29	.7	28	1.93	.7
	Day (19)	187	1.96	.8	87	2.20	.8	83	1.92	.8	83	2.20	.8
	Evening (29)	113	2.12	.8	58	2.06	.7	54	2.33	.8	54	2.05	.7
Fall	Total	506	1.91	.7	320	2.09	.7	297	1.99	.7	297	2.08	.7
	TICCIT	208	1.88	.7	117	2.08	.7	99	1.95	.7	99	2.07	.7
	TICCIT (19)	147	1.79	.7	77	2.14	.7	74	1.92	.7	74	2.14	.7
	TICCIT (29)	61	2.07	.8	40	1.96	.7	25	2.04	.8	25	1.86	.8
	Lecture	298	1.94	.7	203	2.10	.7	198	2.01	.7	198	2.09	.7
	Lecture (19)	210	1.87	.7	157	2.03	.6	154	1.94	.7	154	2.02	.6
	Lecture (29)	88	2.11	.8	46	2.34	.8	44	2.26	.8	44	2.34	.8
	Day (19)	357	1.84	.7	234	2.06	.7	228	1.93	.7	228	2.06	.7
	Evening (29)	149	2.09	.8	86	2.16	.8	69	2.18	.8	69	2.17	.8

Table 5.3

Achievement Summary
Alexandria
English 111
Calendar Year 1976

Objective Test of Writing Skills

								Pretest-Posttest Observations					
		All Pretests			All Posttests			Pretest			Posttest		
Term	Comparison Group	N	Mean	sd	N	Mean	sd	N	Mean	sd	N	Mean	sd
Winter	Total	184	28.55	6.7	96	30.98	6.0	93	29.09	6.3	93	31.38	5.6
	TICCIT	102	30.05	5.5	57	32.18	5.6	55	31.44	4.4	55	32.65	5.1
	Lecture	82	26.70	7.6	39	29.23	6.0	38	25.68	7.0	38	29.53	5.8
Spring	Total	312	26.56	8.8	248	28.31	8.7	236	26.68	8.9	236	28.35	8.8
	TICCIT	116	21.66	8.8	84	22.83	9.2	81	20.68	8.5	81	22.64	9.3
	Lecture	196	29.46	7.4	164	31.12	7.0	155	29.82	7.3	155	31.34	6.9
Fall	Total	259	25.59	7.4	206	28.78	6.4	192	25.70	7.3	192	28.68	6.4
	TICCIT	163	25.60	7.3	122	28.75	6.7	117	25.96	7.3	117	28.63	6.7
	Lecture	96	25.58	7.4	84	28.82	5.9	75	25.29	7.4	75	28.76	6.0
Essay Tests													
Winter	Total	176	2.67	.8	96	2.46	.8	90	2.63	.8	90	2.46	.8
	TICCIT	95	2.71	.8	58	2.72	.8	54	2.75	.8	54	2.71	.8
	Lecture	81	2.63	.7	38	2.07	.8	36	2.46	.7	36	2.08	.8
Spring	Total	311	2.51	.8	248	2.49	.8	236	2.56	.8	236	2.48	.8
	TICCIT	119	2.15	.8	83	2.10	.8	82	2.15	.8	82	2.09	.8
	Lecture	192	2.73	.7	165	2.68	.8	154	2.79	.7	154	2.69	.8
Fall	Total	258	2.14	.7	196	2.36	.8	183	2.14	.7	183	2.34	.8
	TICCIT	162	2.11	.7	113	2.42	.8	107	2.11	.7	107	2.38	.7
	Lecture	96	2.19	.8	83	2.27	.8	76	2.18	.8	76	2.29	.8

Table 5.4

Two points on the objective tests of writing skills or two-tenths of a point on the essay tests would indicate a difference in scores of five percent of the total possible score. Such a difference on either type of test would be equivalent to about one-fourth of a standard deviation. Differences of this size were common for student achievement in math courses but seem rare in English courses.

Even higher pretest means for students completing a course as compared to all students starting a course were infrequent. English 029 is the only case that clearly demonstrates a link between entrance ability and course completion. But entrance ability seldom contributed to the explanation of completion rates in English courses (see Tables 4.8 and 4.9) and when it did represent a significant explanatory variable, it was as part of a trait-treatment interaction. These later instances, English 111 in the winter and fall quarters, were cases in which students completing a course with TICCIT had slightly higher scores on the objective pretest than all students who had started the course in TICCIT classes (e.g., 31.44 and 30.05 in the winter quarter) while students completing the course in the lecture-discussion condition had slightly lower scores than all students who had started under that condition (e.g., 25.68 and 26.70 in the winter quarter). Although there was evidence of a differential treatment effect on course completion (see Chapter 4: Course Completion Rates), it apparently was a subtle phenomenon and should not invalidate the achievement analyses for English courses.

The most obvious differences in test performance arose in Alexandria. During the winter quarter the mean scores associated with the TICCIT condition were about one standard deviation higher than those for lecture-discussion instruction on both the objective pretest and the essay posttest. The objective posttests and essay pretests reflected differences in the same direction though not of the same magnitude. Again in the spring quarter there were gross differences in test performance by condition. The mean scores of the two comparison groups were about one standard deviation apart on all tests. But the differences were in the opposite direction. During the spring quarter the better students in terms of entrance ability were in lecture-discussion classes. Evidently the comparison groups in these two terms were not equivalent at the outset of the course. This fact is not so much a function of inadequate evaluative controls over group composition as it is a result of a conscious effort by the college to try the TICCIT program with students of different abilities. By the fall quarter arrangements had been made for a stronger test of the TICCIT program as an adjunctive resource integrated with classroom practices. The descriptive test data for that quarter suggest that comparison groups were similar in terms of their entrance ability, and data on the time students spent on the TICCIT system (see Chapter 7: Student Activities) indicate extensive use of the TICCIT program.

Data from the fall semester at Phoenix also reveal a sizeable difference in test performance. Students completing English 029 on the TICCIT system had an average score on the essay posttest of 1.86 while the average of students from lecture-discussion classes was 2.34. Entrance ability as reflected by the essay pretest probably accounts for some of this gap on the essay posttest. It seems to us more likely that the part-time instructors responsible for TICCIT classes that semester were unfamiliar with the program and unable to take advantage of its strengths. This disparity in essay posttest scores can be attributed to instructor effects rather than the treatment.

Other differences between pretest and posttest performance might be noted, but this would be an improper interpretation of the data since the English pretest and posttest were separate instruments. Score differences between pretest and posttest do not reflect gains. Nor does it seem appropriate to belabor differences across courses, despite the use of the same instruments as pretests and posttests. The English courses at the two colleges were intended to serve different student populations and had different emphases. But the achievement results for English courses do require analyses to make effects clear.

5.3 Analysis of Program Effects

The achievement data from pretesting and posttesting leave the issue of TICCIT's impact on cumulative learning unsettled. Simple inspection of the results does not rule out the possibility that entrance knowledge accounts for the generally higher posttest performance of students completing math courses under the TICCIT program. Similarly, the differences in test performance observed in English courses seem to be too small to draw conclusions from the data alone about the effectiveness of TICCIT instruction relative to lecture-discussion practices. So we must turn to analyses of these data in order to determine whether there were significant treatment effects on student achievement.

Often an apparent treatment effect can be attributed to sources other than the program under study. It may be some student characteristic (e.g., entrance ability) or a variable associated with particular classes (e.g., the instructor) that accounts for differences in posttest scores seemingly due to the instructional condition. There may also be characteristics of the tests themselves that disguise treatment effects (e.g., posttest coverage weighted toward one program or pretest reliabilities indicating a greater error of measurement within one comparison group). Even further, data taken from a few academic terms for several courses may reveal an effect peculiar to the conditions of one specific term or the materials appropriate to one particular course. All of these considerations enter into our analyses for student achievement so that we might isolate and estimate TICCIT effects.

5.3.a Math Courses

The posttests prepared as measures of student achievement in math courses actually gave a number of different subscores. The basis for our comparisons of TICCIT results with those of regular classroom practices was the subscore that reflected course objectives shared by both conditions. This subscore for common objectives typically included about 85 percent of the items on a course's posttest. The other items concerned objectives unique to either the TICCIT program or lecture classes, and often two or three questions went beyond the course's objectives regardless of condition. The analyses presented here deal first with common objectives and then with objectives unique to one condition.

It may be recalled that our approach to data analysis involved estimating treatment effects for similar students. Similarity was to be defined by a number of demographic variables, such as a student's entrance ability in the subject matter and age. Requiring these additional data meant the loss of some observations in the analysis due to incomplete information. This happened in the analyses for course completion, but the number of observations was so large that we could afford the loss. With the number of pretest-posttest observations already low for math courses under the TICCIT program, we had to retain all of the observations and chose not to sacrifice any for missing demographic data. The variable that defined student similarity in the analyses for achievement in math courses was entrance ability as measured by our pretests.

Tables in this section present the analyses for student achievement as a program outcome in math courses. Each course appears along with a simplified regression model for the posttest score under consideration. That score may correspond to the number of items correct related to common objectives, a particular ability level (e.g., factual recall, solution of routine problems), a specific content category (e.g., arithmetic, algebraic equations, number line and coordinate plane), or objectives unique to one condition. Whatever the particular subscore represents, it is part of the posttest and therefore serves as the dependent variable in the regression model. Usually just two or three terms appear as independent variables in the regression. One is for entrance ability and defines similar students under each condition through their pretest scores. Another might be a simple dichotomous variable representing two different divisions (i.e., day and evening) or terms (i.e., winter and spring). And there is always a term representing the instructional conditions. The regression coefficient for this term is the estimated treatment effect, $\hat{\tau}$.

Common Objectives. Tables 5.5 and 5.6 present the analyses for program outcomes in terms of posttest scores on common objectives. In contrast to the analyses for course completion, the TICCIT impact on student achievement tends to be positive. Eight of the 11 cases presented in the tables show that students completing math courses under the TICCIT program had higher posttest scores than similar students from lecture classes. A statistically significant difference was associated with two cases: Math 007 in the fall semester at Phoenix and Math

Achievement Results: Analysis on Common Objectives
Phoenix Math Courses
Academic Year 1975-76

Course	Math 007	Math 106	Math 108
Term	Fall Semester	Fall Semester	Fall Semester
Number of Students	N = 152	N = 71	N = 47
Multiple Correlation	R = .71	R = .45	R = .47
Standard Error of Estimate	$se_{est} = 6.01$	$se_{est} = 5.01$	$se_{est} = 7.63$

Independent Variables	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition: TICCIT(1)/Lecture(0)	2.87	2.05*	2.18	1.71	3.24	1.01
Entrance Ability: Pretest	.53	11.56***	.23	3.12***	.35	3.04***
Division: Day(1)/Evening(0)	4.30	3.94***				
Constant	8.80		15.50		16.21	

Course	Math 007	Math 106	Math 108	Math 117
Term	Spring Semester	Spring Semester	Spring Semester	Spring Semester
Number of Students	N = 172	N = 91	N = 52	N = 64
Multiple Correlation	R = .58	R = .67	R = .34	R = .73
Standard Error of Estimate	$se_{est} = 6.02$	$se_{est} = 5.87$	$se_{est} = 7.16$	$se_{est} = 5.41$

Independent Variables	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition: TICCIT(1)/Lecture(0)	.36	.29	.73	.26	-.17	-.07	-3.05	-1.72
Entrance Ability: Pretest	.38	8.88***	1.50	7.60***	.20	1.92	.51	2.43*
Division: Day(1)/Evening(0)	2.37	2.40*	1.95	1.47	-4.56	-1.53	10.35	6.07***
Constant	17.63		3.97		29.48		8.17	

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*p < .05

**p < .01

***p < .001

Table 5.5

Achievement Results: Analysis on Common Objectives
Alexandria Math Courses
Academic Year 1975-76

Course	Math 31		Math 31		Math 31		Math 32	
Term	Fall Quarter		Winter Quarter		Spring Quarter		Winter & Spring Quarters	
Number of Students	N = 48		N = 36		N = 18		N = 44	
Multiple Correlation	R = .55		R = .46		R = .64		R = .51	
Standard Error of Estimate	$se_{est} = 4.49$		$se_{est} = 5.15$		$se_{est} = 4.95$		$se_{est} = 4.62$	
Independent Variables	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition: TICCIT(1)/Lecture(0)	1.79	.98	2.91	1.67	- .93	- .40	4.31	2.15^{*}
Entrance Ability: Pretest	.24	3.51^{**}	.22	2.43^{*}	.30	3.15^{**}	.56	2.27^{*}
Term: Winter(1)/Spring(0)							1.99	1.31
Constant	24.37		24.75		22.93		7.45	

$^{*}p < .05$

$^{**}p < .01$

$^{***}p < .001$

Table 5.6

32 at Alexandria. Both involve a point difference in favor of the TICCIT program. There were three cases of a negative treatment effect, but none of these was significant at accepted levels of probability.

These results hardly seem overwhelming. It might be said instead that nine of 11 cases showed no significant difference in student achievement. That would seem to be a fair interpretation, especially if some alternative explanation exists for the significant positive effects. For Math 32 at Alexandria there were very few pretest-posttest observations in the TICCIT condition. The seven students representing that population which received a passing grade for Algebra II on the TICCIT system would certainly temper our interpretation of the educational significance of the treatment effect. Indeed, an analysis conducted for all students posttested regardless of grade would indicate an effect in the opposite direction. The treatment effect would then be -1.35 and its associated t-statistic -.99 (based on 32 observations within the TICCIT condition and 47 within lecture). Hence, the difference in posttest performance goes against the TICCIT condition for students attending classes for Math 32.

The other case of a significant treatment effect was Math 007 in the fall semester at Phoenix. Since the pretest reliability for students with posttests was .83 within the TICCIT condition and .93 within the lecture condition, perhaps the treatment effect was an artifact of a test characteristic. But the analysis, corrected for pretest reliability (after Porter & Chibucos, 1974), would yield an even higher estimate of the treatment effect, $\hat{\tau} = 3.13$ and $t = 2.14$, $\underline{p} < .05$. Similarly, the pretest-posttest correlations varied so much by condition, .46 within the TICCIT condition and .78 within lecture, that this might be seen as a strong competing explanation for the apparent treatment effect. Yet we should expect such a reduced pretest-posttest correlation within the TICCIT condition given the restricted pretest range among students completing a math course under the TICCIT program. If we accept this experimental effect on course completion rates and correct the analysis for unreliability according to test-retest correlations (after Campbell & Borich, 1975), the estimated treatment effect ($\hat{\tau} = 2.75$ and $t = 1.88$) would still be consistent with our original estimate in Table 5.5 ($\hat{\tau} = 2.87$ and $t = 2.05$). Nor is the effect simply a matter of systematic bias due to posttest observations without pretests. Adjusting for missing pretests would reveal a somewhat higher treatment effect, $\hat{\tau} = 3.30$.

It might still be argued that entrance ability accounts for the better performance of students in the TICCIT condition. To some extent it does: almost every analysis indicates that pretest score contributes significantly to the explanation of posttest variance. But with entrance ability taken into consideration there was a significant treatment effect. Even comparisons of just those students with similar pretest scores would indicate that the TICCIT program has a positive effect on cumulative learning. Such an analysis, for Math 007 in the fall semester, with the range of pretest scores in the lecture condition restricted to $X \geq 35$ as an approximate match to observed scores in the TICCIT condition, would result in an estimated treatment effect of 2.37 and a t-statistic of 1.93. The positive TICCIT effect for Math 007 in the fall semester holds under a variety of analyses.

Actually the treatment effect evident in Math 007 for the fall semester was even more dramatic than the estimates thus far presented suggest. There was a statistically significant interaction term omitted from the simplified regression model in Table 5.5. It indicated that the treatment effect was different in the day and evening divisions. Although the point difference in posttest performance by condition was positive for the day division, $\hat{\tau}_D = 1.14$, the estimated treatment effect for the evening division was quite pronounced, $\hat{\tau}_E = 8.43$ and $t = 2.99$, $p < .01$. Sample size in the evening division for the TICCIT condition ($N = 9$) precluded reliability adjustments within groups defined by both condition and division. However, if we were to include a treatment x division term in our analyses corrected for test unreliability, we would find both the adjustment for pretest reliability and that for test-retest correlation show a similar estimated treatment effect for the evening division ($\hat{\tau}_E = 8.46$ and $t = 3.01$, $p < .01$, and $\hat{\tau}_E = 8.59$ and $t = 3.06$, $p < .01$, for the two methods, respectively). These results conform with our findings for Math 007 across semesters (see Table 5.8) as well as the appearance of the data (see Table 5.1). And they lend further weight to the interpretation of the TICCIT effect on student achievement as positive and significant for mainline applications in math courses.

This evidence of a treatment effect should convince us to look elsewhere for supporting results. The analyses presented in Table 5.5 for the spring semester at Phoenix included only those students who completed their course studies by the end of the academic term. Yet there were some students who took advantage of the self-paced nature of the TICCIT program and concentrated on other courses instead of completing their math course on the TICCIT system. Later they did fulfill their math course's requirements. Including these students in the analyses for the spring semester would give us four more observations in both Math 106 and Math 108, a substantial increase given the low sample size for the TICCIT condition in these courses. Also, data collection for Math 106 and Math 117 continued into the summer semester; six additional observations for the TICCIT condition in each of these courses become available.

Analyses which include students completing a math course after the formal close of the spring semester or during the summer semester appear in Table 5.7. There would be only two additional observations in Math 007 for TICCIT completions immediately after the spring semester, so that course is omitted from the table. For the three courses which do appear, there is an increase in the estimated treatment effects over those obtained from posttest data collected within the spring semester. Now we find estimates of a significant, positive TICCIT effect for Math 106 and Math 117. Since the data for Math 106 include six students from the TICCIT condition in the summer semester but no students from lecture classes in that term, there is reason to question the estimated treatment effect. The regression weight listed for Math 117 indicates a sizeable point difference between conditions, 6.14 points or about three-fourths of a standard deviation. However, there is an interaction term in this regression model. The actual estimated effect in the day division would be a combination of terms:

$\hat{\tau}_E = 6.14$ for students completing an evening TICCIT class and

$\hat{\tau}_D = 6.14 + (-7.88) = -1.74$ for students completing a day TICCIT class.

The significant effect of 6.14 applies to the evening division alone, and just four students of the 20 observations in the TICCIT condition represent the relevant population. The small sample size may therefore raise doubt about the results for Math 117.

At Alexandria it is possible that students completing a math course under the TICCIT program within one academic term would demonstrate the program's effectiveness. There were just 33 such students in the winter quarter with both a pretest and a posttest for Math 31 (13 for the TICCIT condition, 11 for

Achievement Results: Analysis on Common Objectives
Math Courses at Phoenix
Spring and Summer Semesters, 1976

Course	Math 106	Math 108	Math 117
Number of Students	N = 101	N = 56	N = 99
Multiple Correlation	R = .67	R = .30	R = .71
Standard Error of Estimate	$se_{est}=5.77$	$se_{est}=7.33$	$se_{est}=5.33$

Independent Variables:	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition:						
TICCIT(1)/Lecture(0)	3.37	2.07*	.97	.43	6.14	2.05*
Entrance Ability:						
Pretest	1.44	7.64***	.16	1.56	.66	3.93***
Division:						
Day(1)/Evening(0)	1.49	1.21	-4.62	-1.51	-1.22	-.62
Term:						
Spring(1)/Summer(0)					-11.16	-5.79***
Interactions:						
Day & Spring					-11.18	4.57***
TICCIT* Day					-7.88	-2.36*
Constant:	5.05		31.31		17.46	

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*p < .05

***p < .001

Table 5.7

lecture and 9 for programmed instruction). The analysis of these data would indicate a significant, positive treatment effect: $\hat{\tau} = 4.60$ and $t = 2.19$, $p < .05$, for a comparison of the TICCIT and lecture conditions; $\hat{\tau} = 3.66$ and $t = 2.19$, $p < .05$, for a comparison of the TICCIT and programmed conditions. The small numbers of observations might once again tempt us to dismiss these results. To do so would be to disregard a significant effect for the third time, counting Math 32 in the winter and spring quarters, Math 106 in the extended spring semester, and now Math 31 in the winter quarter. The sample size may indicate that our estimated effects apply to a select group of students, but nevertheless they constitute evidence of TICCIT's impact on student achievement.

It appears that when we remove the time constraints of an academic term, the sample size increases and the variable representing the instructional condition is more apt to become a significant term in the regression model. This happened for Math 32 (Table 5.6), Math 106, and Math 117 (Table 5.7) when posttest data were taken from multiple terms. Table 5.8 presents analyses for the introductory algebra courses, Math 007 and Math 31, across academic terms. With relaxed time constraints a positive TICCIT effect becomes apparent in both courses. At Phoenix the effect was 5.40 points on the posttest score for common objectives. This difference corresponds to approximately two-thirds of a standard deviation or better than ten percent of the total score possible. It applies only to the evening division, as indicated by the treatment-division interaction term in the regression model and suggested by the summary of achievement data (see Table 5.1). At Alexandria the effect in the day division was 4.39 for a comparison of TICCIT results with those of lecture classes. Such a point spread between conditions is equivalent to ten percent of the total score

Achievement Results across Terms: Analysis on Common Objectives
Alexandria and Phoenix
Math 31 and Math 007
Academic Year 1975-76

			Math 31		Math 31	
	Math 007		Students with Credit		Students with Credit	
Number of Students	N = 331		N = 87		N = 110	
Multiple Correlation	R = .65		R = .64		R = .58	
Independent Variables:	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition:						
TICCIT(1)/Lecture(0)	5.40	2.69^{**}	-.11	-.06		
TICCIT(1)/Programmed(-1)					1.33	1.93
Lecture(1)/Programmed(-1)					-1.08	-1.78
Entrance ability:						
Pretest	.45	14.53^{***}	.21	4.04^{***}	.17	4.08^{***}
Academic Term:						
Fall(1)/Spring(0)	-1.36	-2.00^{*}				
Fall(1)/Spring(-1)			.68	.93	.44	.67
Winter(1)/Spring(-1)			.10	.12	.32	.52
Division:						
Day(1)/Evening(0)	3.62	4.67^{***}	-3.16	-2.07^{*}	- .97	- .79
Student Status:						
Full-time(1)/Part-time(0)			-1.40	-1.17	-1.21	-1.10
Employment:						
Full-time(3)/Part-time(2)/None(1)			- .28	- .40	- .89	-1.39
Enrollment in Course:						
Prior enrollment(1)/First enrollment(0)			-1.83	-1.45	-2.35	-2.22^{*}
Maturity:						
Age (Years)			- .14	-1.73	- .03	- .43
Interactions:						
TICCIT*Day	-5.47	-2.45^{*}	4.50	2.12^{*}		
Constant:	14.12		32.48		28.65	

$^{***}p < .001$

$^{**}p < .01$

$^{*}p < .05$

Table 5.8

possible on common objectives. The estimated effect was less for TICCIT results compared with those of programmed instruction. Then the regression coefficient was 1.33, which corresponds to a $\hat{\tau}$ of 2.66 points and approaches accepted limits for statistical significance. The lower effect for TICCIT when compared against programmed instruction should be expected since there were fewer posttest items common to these two conditions (38 rather than 44) and this estimate, unlike that obtained with lecture as a relative standard, held for day and evening classes.

Students able to complete a math course on the TICCIT system do attain higher posttest scores than comparable students from lecture classes. These treatment effects on student achievement may not be readily apparent from analyses conducted for each academic term. However, the TICCIT program offers students self-paced instruction. This both removes much of the need for students to meet a fixed time constraint, and introduces a temptation for them to neglect a TICCIT class. Especially toward the end of an academic term when the demands of other courses must be met, students may choose to take advantage of TICCIT's self-paced feature and plan to continue studying on the TICCIT system after the formal close of a term. So analyses of achievement data collected within an academic term may not reveal treatment effects. But analyses across academic terms show a significant, positive treatment effect in five math courses of six.

Ability and Content Subscores. Regardless of its overall impact on student achievement, the TICCIT program might be particularly strong or weak for certain components of the math curriculum. Such a view is consistent with the belief that competing curricular programs may lead to different patterns of test performance rather than any difference in aggregate achievement (see Walker & Schaffarzick, 1974). Certainly if test coverage favors one curriculum or another, there should be achievement differences reflecting that bias. But if we restrict comparisons to just those test items reflecting objectives shared by the competing curricula, we can eliminate possible sources of test bias. Then comparisons of competing curricular programs would yield fair estimates of their relative advantages for specific outcomes. All of our comparisons for detecting relative advantages on specific achievement outcomes draw on course objectives common to the TICCIT program and the conventional math program.

The subscores formed from common posttest items reflect two dimensions of the math curriculum. One series of subscores divides test items into four separate ability levels: (0) factual recall; (1) manipulation; (2) solution of routine problems; and (3) demonstration of concept comprehension. The order of these four ability levels constitutes a progression from cognitive tasks requiring just knowledge, to others demanding comprehension, to those calling for the straightforward application of rules, and finally to tasks necessitating the analysis of concept relationships in unfamiliar problem situations (see Bloom, 1956). Another dimension corresponds to the content categories within a test: (1) arithmetic; (2.a) simplifying signed and complex numbers; (2.b) equations; (2.c) exponents, radicals and logarithms; (2.d) factoring, multiplying and dividing algebraic expressions; (2.e) number line and coordinate plane; (2.f) inequalities, absolute values and sets; (2.g) sequences, arithmetic and geometric progressions; and (2.h) permutations and combinations, binomial theorem. These content categories represent a classification of the complete precalculus curriculum. Not every category appears on each posttest. The posttests for beginning algebra do not cover progressions or permutations and combinations, while those for intermediate algebra omit items on arithmetic. The actual number of items within each ability level or content category probably gives a strong indication of course emphasis.

Naturally the common objectives broken down further to ability or content subscores leave few items to define a specific outcome. Therefore, our measurement of specific outcomes cannot be as reliable as the total score on common objectives. Table 5.9 presents reliability estimates for posttest subscores. Although some approach an acceptable reliability for group measures (i.e., r= .80), most seem too unreliable for firm conclusions about specific program outcomes. The results of data analyses for subscores do provide descriptive evidence that should be useful in planning applications of the TICCIT program or developing computer-assisted instructional systems.

Appendix P contains summaries of student performance on the math posttests. The mean and standard deviation appear for each subscore along with the number of items in that subscore. From these data we took subscores on ability levels and content categories. Each score became the dependent variable in a regression analysis similar to those shown in Tables 5.5 and 5.6. These were fallible dependent variables in that they often included as much variation due to error as due to true score. Interpretation of subscore results was further complicated by the large number of analyses. Since a course's posttest had subscores for four ability levels and six or more content categories, there were at least ten analyses per course.

Table 5.10 presents the results of these analyses in the courses for which subscore reliabilities were given by an earlier table (see Table 5.9). It includes the regression coefficient and t-statistic for the independent variable that represented the instructional condition in each analysis. As before, the

Posttest Subscore Reliability: Internal Consistency Estimates
Alexandria and Phoenix
Mathematics Courses
Academic Year 1975-76

	Math 007			Math 31				Math 117		Math 32	
		Fall (N = 182)	Spring (N = 181)		Fall[2] (N = 58)	Winter (N = 80)	Spring (N = 79)	Spring (N = 71)		Winter and Spring (N = 92)	
Objectives	Number of Items	r	r	Number of Items	r	r	r	Number of Items	r	Number of Items	r
2 Unique to lecture	5	.67	.61	1				2		0	
3 Unique to TICCIT	4			9	.51	.45	.66	3		4	
4 Beyond curriculum	0			0				3		3	
Ability Levels											
0 Factual Recall	2			2				1		1	
1 Manipulation	19(18)[1]	.81	.69	15	.54	.82	.83	5	.46	3	
2 Routine Problem Solving	22(17)	.79	.73	22(18)[1]	.66	.84	.86	16(11)	.75	18(16)	.69
3 Concept Comprehension	14(11)	.63	.48	15(9)	.45	.65	.76	24(21)	.82	19(14)	.74
Content											
1 Arithmetic	12(10)	.64	.47	12(11)	.56	.69	.75	0		0	
2 Algebra											
a simplifying	6(5)	.66	.49	7	.40	.75	.73	3		3(1)	
b equations	18(17)	.83	.76	15(14)	.63	.82	.85	16	.75	12(10)	.71
c exponents, radicals	5	.47	.40	7(4)				3(1)		14(13)	.65
d algebraic expressions	10(7)	.70	.64	4				4(3)		3	
e number line and coordinate plane	3			5(3)				12(11)	.77	5(4)	
f inequalities, absolute value	3(1)			4(1)				1		4(3)	
g sequences and progressions								4(2)			
h permutations and combinations								3(1)			

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[1] The number of items in parentheses reflects only those items on common objectives. Responses to these common items were the basis for reliability estimates.

[2] In the fall quarter, the reliability estimates were taken from data on those students who received course credit.

Table 5.9

Achievement Results: Analysis of Posttest Subscores
Ability Levels and Content Categories
Alexandria and Phoenix
Math Courses
Academic Year 1975-76

Course	Math 007		Math 007		Math 117		Math 31		Math 31		Math 32	
Term	Fall Semester		Spring Semester		Summer Semester		Fall Quarter		Winter Quarter		Winter & Spring Quarters	
Number of Students	N = 152		N = 172		N = 99		N = 48		N = 36		N = 44	
Dependent Variables	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Ability Levels:												
Factual Recall	.10	1.16	.10	1.21	-.24	-1.85	.10	.44	.01	.08	.33	1.58
Manipulation	.63	1.05	.13	.25	-.04	-.17	.16	.21	1.38	2.60*	-.17	-.42
Solution of Routine Problems	1.75	2.84**	.11	.20	.00	.00	1.25	1.25	.79	.81	2.57	2.62*
Demonstration of Concept Comprehension	.38	.89	.01	.03	.44	.45	.29	.59	.72	1.48	1.57	1.37
Content Categories:												
Arithmetic	.07	.21	.00	.00			.44	.71	.98	2.26*		
Algebra-												
Simplifying	-.24	-.91	-.10	-.45	-.23	-1.09	.06	.16	.34	1.21	.08	.35
Equations	2.53	3.54***	1.26	2.20*	.52	.71	.76	1.01	.66	.98	1.54	1.67
Exponents, Radicals, Logarithms	.13	.47	-.55	-2.34*	.17	1.60	.65	1.34	.90	2.00	1.69	2.43*
Factoring, Multiplying, Dividing Expressions	.20	.58	-.28	-.88	-.42	-1.90	-.12	-.32	-.11	-.24	.49	1.47
Number Line and Coordinate Plane	.17	1.02	.15	.91	-.43	-.77	.06	.22	.20	.72	.14	.29
Inequalities, Absolute Values	-.01	-.07	-.13	-1.27	.12	1.00	-.07	-.38	-.05	-.31	.37	.99
Sequences, Progressions					.24	1.31						
Permutations, Combinations					.20	1.68						

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*p < .05
**p < .01
***p < .001

Table 5.10

coefficients correspond to the estimated point difference between outcomes of the TICCIT program and those of the lecture condition. Perhaps the most striking feature of these results is the absence of significant treatment effects. With so large a number of analyses we might expect to find more than eight significant effects for specific outcomes. And the significant treatment effects on test performance taken as total score on common objectives would reinforce such an expectation. But three facts should reduce the number of significant findings: the elimination of possible sources of test bias by considering only items on common objectives; the fallible nature of subscores as dependent variables; and the breakdown of a possibly significant overall effect into several smaller parts.

Only two significant effects were repeated in another math course or academic term. One corresponds to the solution of routine problems as an ability level and the other to equations as a content category. Both of these specific outcomes involved an effect in favor of the TICCIT program. The point differences reflected by the regression coefficients were always positive for these two subscores, and they were significant in two cases for each outcome (Math 007 in the fall semester and Math 32 in the winter and spring quarters for the solution of routine problems, and Math 007 in the fall semester and again in the spring semester for equations). Further, the estimated treatment effects for Math 106 in the fall semester were positive and significant for both the solution of routine problems, $\hat{\tau} = 2.29$ and $t = 2.86$, $p < .01$, and equations, $\hat{\tau} = 1.13$ and $t = 2.72$, $p < .01$, as specific outcomes.

The probable reasons for these two specific strengths in the TICCIT program come from a fundamental feature of its design and the detail of its content coverage. The computer system provides students with access to an extensive file of practice exercises for learning and repeating rules of problem solving. Students take advantage of this opportunity and spend most of their time on the TICCIT system doing practice problems (see Chapter 7: Student Activities). One result of their repetitious practice in applying rules is improved performance in solving routine problems. The advantage for the TICCIT program in posttest subscores related to equations may be attributed to the depth of its coverage on this topic (see Appendix A, in particular Unit 20). It seems for the topic of equations the developers succeeded in isolating the key attributes of rules and providing appropriate instances of rule applications as examples and practice problems.

A final point about the ability and content subscores should be noted. It concerns the absence of significant effects. The TICCIT program resulted in test performance comparable to lecture results for the highest ability level and most advanced content category. The direction of differences on these specific outcomes showed consistently positive TICCIT effects. The program's impact on student achievement was not just a matter of rote factual recall or simple arithmetic operations. It affected student achievement in substantial and substantive parts of the math curriculum: the solution of routine problems and equations. The TICCIT program also held its own on specific outcomes for which conventional practices might be thought to be more conducive to student learning.

Unique Objectives. Few of the posttest items represented objectives unique to either the TICCIT program or lecture instruction. There was substantial overlap in course objectives across conditions since all classes had to meet the same curricular requirements. However, one-sixth of the posttest items for Algebra I represented material taught only in TICCIT classes. This is a reflection on the ambitious coverage of that course under the TICCIT program (see Figure 2.1); the posttest for Math 31 merely makes the discrepancy in coverage explicit. Usually, fewer than ten posttest items corresponded to unique objectives (see Appendix C and Table 5.9), and these were split among objectives unique to the TICCIT condition and objectives unique to the lecture condition.

Table 5.11 presents the results of the analyses for posttest subscores on unique objectives. The estimated treatment effects here are subject to the same qualification that applied to ability and content subscores: the dependent variable is a fallible measure of specific program outcomes. But the statistical tests of significance suggest a clear pattern of the results. Students taking a math course on the TICCIT system did attain higher posttest subscores on objectives unique to the TICCIT program, while students in lecture classes attained higher posttest subscores on objectives unique to the lecture condition. Had such a pattern not been obvious, there would be reason for doubting the classification of posttest items by objectives. Instead it seems the procedures for classifying items worked well and, hence, the comparisons of program results according to common objectives were fair.

The estimated treatment effects given in Table 5.11 also suggest that program comparisons based on total posttest scores would lead to greater observed differences in test performance. At least this would be so for Math 31. For that course, including items on unique objectives might increase the overall point difference between conditions. Another point added to the TICCIT effects already estimated for Math 31 (see Table 5.8) would provide further evidence of a positive TICCIT impact on student achievement.

Achievement Results: Analysis on Unique Objectives
Alexandria and Phoenix
Math Courses
Academic Year 1975-76

			Dependent Variable			
			Posttest Items Unique to Lecture		Posttest Items Unique to TICCIT	
Course	Term	Number of Students	Regression Weight ($\hat{\tau}$)	Value of t-statistic	Regression Weight ($\hat{\tau}$)	Value of t-statistic
Math 007	Fall Semester	152	-1.73	-5.80***	.91	4.04***
Math 007	Spring Semester	172	- .85	-2.97**	.86	4.24***
Math 117	Spring & Summer Semesters	99	.09	.48	.49	2.53*
Math 31	Fall Quarter	48	- .02	- .11	1.51	3.02**
Math 31	Winter Quarter	36	.19	1.33	1.09	1.97
Math 32	Winter & Spring Quarters	44			.30	.82

$^{*}p < .05$

$^{**}p < .01$

$^{***}p < .001$

Table 5.11

5.3.b English Courses

The posttests prepared as measures of student achievement in English courses had two distinct components. There was an objective test of writing skills that covered traditional points in composition (see Appendix E). It presented questions about grammatical and structural conventions in standard written English and called for responses in a multiple-choice format (see Figure 2.5). Obviously such a test, as an indirect measure of writing ability and a sample of pertinent skills, had limitations. The English posttests, therefore, included an essay component (see Appendix D). Students wrote on a given topic under test conditions, and instructors later assigned scores to these essays in grading sessions supervised by the evaluator. A student's scores on the objectives and essay components served as complementary but separate measures of achievement.

For English courses the question of program impact on student achievement became a matter of point differences on either the essay or objective test. Analyses again took the form of regression models. A component of the English posttest was the dependent variable, and the independent variables defining similar students in each condition were the same as those employed in the analyses for course completion. The estimates of treatment effects, then, represent the difference in scores between students completing an English course on the TICCIT system and comparable students from lecture-discussion classes.

Tables 5.12 and 5.13 present the analyses for student achievement as a program outcome. It may seem as though the estimated treatment effect was negative as often as positive. The regression coefficients for the term representing the instructional conditions were negative in six of ten cases.

Achievement Results: Essay and Objective Tests
Phoenix
English 19 and 29
Calendar Year 1976

Posttest	Essay		Objective		Essay		Objective	
Term	Spring Semester		Spring Semester		Fall Semester		Fall Semester	
Number of Students	N = 105		N = 105		N = 248		N = 244	
Multiple Correlation	R = .58		R = .73		R = .61		R = .64	
Standard Error of Estimate	se_{est} = .66		se_{est} = 4.30		se_{est} = .57		se_{est} = 4.61	
Independent Variables:	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition:								
TICCIT(1)/Lecture(0)	.204	1.42	-3.77	-1.35	-.498	-3.03**	1.68	2.41*
Entrance ability:								
Essay Pretest	.318	3.42**	1.91	3.06**	.279	4.56***	1.01	2.06*
Objective Pretest	.035	3.19**	-.45	-1.07	.036	5.69***	.44	8.59***
Division:								
Day(1)/Evening(0)	.341	1.87	-1.42	-1.20	-.267	-1.81	1.12	1.05
Instructor:								
I1	-.284	-1.26	-.31	-.21	-.234	-1.74	-1.43	-1.40
I2					.082	.64		
Student status:								
Full-time(1)/Part-time(0)	-.097	-.63	1.71	1.68	.179	1.59	.23	.25
Enrollment in course:								
Repetition of course(1)/ First enrollment(0)	-.503	-1.41	-1.22	-.57	-.315	-1.19	-.12	-.05
Employment:								
Full-time work(3)/ Part-time(2)/None(1)	-.138	-1.31	-.29	-.44	-.026	-.46	-.08	-.16
Maturity:								
Age(Years)	-.002	-.01	-.04	-.23	-.003	-.42	.11	2.14*
Sex:								
Male(1)/Female(0)	.080	-.52	-.16	-.15	-.088	-1.17	.31	.83
Interaction:								
Objective Pretest^2			.02	2.11*				
TICCIT* Age			.23	2.30*				
TICCIT* Day					.581	2.95**		
Constant--	.848		22.48		.974		10.31	

$^*p<.05$

$^{**}p<.01$

$^{***}p<.001$

Table 5.12

Achievement Results: Essay and Objective Tests

Alexandria
English 111
Calendar Year 1976

Posttest	Essay		Objective		Essay		Objective		Essay		Objective	
Term	Winter Quarter		Winter Quarter		Spring Quarter		Spring Quarter		Fall Quarter		Fall Quarter	
Number of Students	N = 82		N = 83		N = 200		N = 200		N = 158		N = 167	
Multiple Correlation	R = .62		R = .76		R = .70		R = .34		R = .55		R = .75	
Standard Error of Estimate	$se_{est} = .69$		$se_{est} = .76$		$se_{est} = .61$		$se_{est} = 4.76$		$se_{est} = .65$		$se_{est} = 4.25$	
Independent Variables:	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition:												
TICCIT(1)/Lecture(0)	.235	1.00	-.93	-.68	-.164	-1.17	-7.79	-3.09**	.420	2.11*	-.90	-1.14
Entrance ability:												
Essay Pretest	.178	1.60	3.36	5.20***	.202	2.71**	1.09	1.93	.113	1.40	.89	1.74
Objective Pretest	.053	3.29**	.42	4.56***	.043	6.04***	.54	7.97***	.040	4.67***	.57	10.41***
Division:												
Day(1)/Evening(0)	.088	-.22	1.03	.43	.141	.94	-1.26	-1.06	.356	1.49	.45	.42
Class:												
Laboratory(1)/Regular(0)	-.065	-.24	-.91	-.58			-2.25	-2.63**				
Instructor:												
I1									-.213	-1.05	-1.94	-1.57
I2									.149	.72	1.20	.94
I3									.105	.52	.07	.05
I4									.325	1.75	.28	.25
Student status:												
Full-time(1)/Part-time(0)	.140	.59	-1.57	-1.14	-.059	-.50	.72	.79	.226	1.43	2.23	2.25*
Enrollment in course:												
Repetition of course(1)/ First enrollment(0)	.470	1.63	.88	.55	.189	.85	1.91	1.11	.199	.77	.64	.38
Employment:												
Full-time work(3)/ Part-time(2)/None(1)	.209	1.76	-.83	-1.22	-.021	-.33	-.51	-1.00	-.003	-.03	.19	.35
Maturity:												
Age(Years)	.019	1.58	-.13	-1.83	-.001	-.17	-.01	-.28	.011	1.34	.01	.20
Sex:												
Male(1)/Female(0)	-.151	-.91	2.62	2.74**	-.068	-.70	-1.55	-2.09*	-.007	-.07	1.03	1.54
Interaction:												
TICCIT* Objective Pretest							.26	2.75**				
TICCIT* Day									-.560	-2.25*		
Constant--	-.417		14.03		1.03		15.39		.383		9.69	

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*p<.05

**p<.01

***p<.001

Table 5.13

And the statistical tests associated with the condition variable were significant four times, twice with positive weights and twice with negative. But these regression coefficients did not necessarily reflect the treatment effect. Whenever an interaction term involving the condition variable accounted for a significant portion of posttest variance, it entered into the regression model. Then estimating treatment effects also meant combining regression weights.

The first analysis, including an interaction term in the regression model, is that for the objective test of writing skills in the spring semester at Phoenix. Actually, the response functions for student achievement in this case were neither linear nor parallel. The addition of the squared score on the objective pretest as an independent variable indicates nonlinearity. The treatment-trait interaction term indicates a relationship between variables in one condition but not the other. Here there was a relationship between a student's score on the objective posttest and his age that held just within the TICCIT condition. Put another way, TICCIT's impact on student achievement varied according to age.

Our best estimate of a treatment effect in cases with trait-treatment interactions is the value of the regression coefficient for the condition term plus the value of the regression coefficient for the interaction multiplied by the trait's mean value within the TICCIT condition. It is much easier to understand this combination of coefficients as it applies to the achievement data from the spring semester. The estimated treatment effect would be:

$$\hat{\tau} = -3.77 + .23(26.46)$$

$$\hat{\tau} = 2.38.$$

It is the weight for the condition term, -3.77, plus the coefficient for the trait-treatment interaction, .23, multiplied by the average age of students within the TICCIT condition, 26.46. Since the population referred to by our estimated treatment effects is always that which completed a course on the TICCIT system, the mean of a trait must be taken from observations for that population. Thus, 26.46 was the mean age of students completing English 019 (or English 29 in the evening division) on the TICCIT system in the spring semester.

The estimated treatment effect of 2.38 points on the objective posttest is significant ($t = 2.48$, $p < .05$) but, in a sense, incomplete. The point difference varied according to age, and estimates made at different intervals in the age distribution would give a fuller picture of effects. At approximately one standard deviation below and above the mean age of TICCIT students, the treatment effects would be .42 for students 18 years of age and 4.37 for students 35 years old. The impact of the TICCIT program on objective test performance was consistently positive at all age levels and apparently increased with age.

The TICCIT program had a positive effect on student achievement across semesters at Phoenix. In the spring semester that effect amounted to 2.38 points on the objective test of writing skills. The same significant, positive effect occurred in the fall semester. Then the point difference in favor of the TICCIT program was 1.68 in terms of score on the objective posttest. This estimated treatment effect was independent of a student's age, but age still served as a significant independent variable by itself, $b = .11$ and $t = 2.14$, $p < .05$. Descriptive achievement data from the summer semester (see Appendix O) provide supporting evidence for a positive treatment effect on objective test performance. But perhaps this occurred at the expense of students' actual writing. Discrete skills might be learned through extensive practice but not applied in essays.

The estimated treatment effects on the essay posttest seem to depict a mixed result for the TICCIT program. The regression coefficient for the term representing the instructional conditions was positive in the spring semester and highly negative in the fall. However, there should be two estimates of treatment effects for the fall semester. The estimate for the day division would be a combination of coefficients, (-.498) + (.581), yielding a slight positive value, $\hat{\tau}_D = .08$. Another for the evening division would be the coefficient for the condition term as it stands, $\hat{\tau} = -.498$ and $t = -3.03$, $p < .01$. The probable reason for this negative effect in English 029 rests in the context for the demonstration. Part-time instructors unfamiliar with the TICCIT program taught evening classes on the computer system during the fall semester, and their inexperience showed in the achievement results. This suggests that instructors must be thoroughly familiar with the TICCIT program in order to teach with it in an effective manner.

At Alexandria there were two instances of a significant treatment effect. The first involved student performance on the objective posttest in the spring quarter. Estimating that effect as a combination of regression coefficients,

$$\hat{\tau} = -7.79 + .26(21.48)$$

$$\hat{\tau} = -2.21,$$

indicates that students who completed English 111 with the TICCIT system scored about two points lower on the objective posttest than similar students in entirely lecture-discussion classes. But the magnitude of the effect varied according to students' scores on the objective pretest, and there should again be several estimates reflecting the range of effects. The estimated effect begins to change direction for students whose objective pretest score exceeded 30: $\hat{\tau} = .01$ when the objective pretest score was approximately one standard deviation above the mean. Only for students with nearly the maximum possible score on the objective pretest would the estimated effect be positive and significant. The significant negative effect, however, applies to over half of the students who completed English 111 with some TICCIT use in the spring quarter. The estimated effect would be -4.41 points for students with objective pretest scores about one standard deviation below the mean observed in the TICCIT condition.

The other significant treatment effect at Alexandria occurred on the essay posttest in the fall quarter. That regression model has an interaction term indicating different effects in the day and evening divisions:

$\hat{\tau}_E = .420$ for students completing evening TICCIT classes and

$\hat{\tau}_D = .420 + (-.560) = -.14$ for students completing day TICCIT classes.

The positive effect in the evening division represents a sizeable point difference between conditions on the essay posttest. However, some of this effect might be attributed to instructors rather than treatments. One instructor apparently stressed writing skills and sacrificed student performance on essay tests in a lecture-discussion class (see Appendix M, the descriptive statistics for section 14 in the fall quarter). Just as the negative impact on essay performance at Phoenix could be explained by certain instructors' lack of familiarity with the TICCIT program, the positive impact observed at Alexandria may be a function of an instructor's emphasis in teaching composition.

The one consistent result from the analyses for student achievement concerned point differences between conditions on the objective test of writing skills. The TICCIT program led to higher scores on the objective posttest, and the point differences were in the neighborhood of two points or about five percent of the total score possible. Such an estimated treatment effect may seem negligible in terms of its educational importance but still represents a significant and uncommon finding. The effect arose from the application of the TICCIT program as a primary instructional resource. Instructors were responsible for directing students and often supplemented the TICCIT curriculum by holding small group discussions. The courses in which the TICCIT program had this positive impact were English 019 and English 029 at Phoenix. These courses placed emphasis on the fundamentals of written English, and the significant treatment effects indicated TICCIT's positive impact on precisely that component of student performance, namely, the objective test of writing skills.

There was also a case of a significant treatment effect on test performance in the spring quarter at Alexandria. The TICCIT program as an adjunctive instructional resource had a negative impact on student achievement: students completing English 111 with some exposure to the TICCIT materials had lower scores on the objective test of writing skills than similar students from lecture-discussion classes. The size of the point difference varied according to entrance ability, defined by scores on the objective pretest. This same trait-treatment interaction between entrance ability and the TICCIT condition had occurred in the analyses for course completion as a program outcome. With that dependent variable the interaction entered into the regression models for the winter and fall quarters (see Table 4.9). Now, with student performance on the objective posttest as the dependent variable, we find evidence of the interaction in the spring quarter as well. Thus, the TICCIT program applied as an adjunct to conventional practices, the condition under which its course completion rates came closest to that of lecture-discussion classes, had a negative impact on some aspect of student performance across quarters of Alexandria, and that effect worsened as scores on the objective pretest fell.

5.3.c Immediate Learning and Retention

Besides the posttests which served as measures of cumulative learning, there were topical tests and tests for retention. These tests defined student achievement in terms of immediate learning and retention, and therefore broadened our evaluation of student achievement in math courses. The topical tests were taken by students in math courses as soon as they completed instruction in a particular topic. The topic tested in introductory algebra was linear equations, and in intermediate algebra it was algebraic expressions. The tests for retention were actually pretests serving a dual purpose. Pretests administered at the beginning of more advanced courses in an algebra sequence acted as both a measure of entrance ability in that advanced course and a measure of retention for the prerequisite course. For a student enrolled for Algebra I and Algebra II in successive academic terms the pretest for Algebra II would also be a retention test for Algebra I.

The results of the analyses for topical testing appear in Table 5.14. Generally the estimated treatment effects, represented by the regression weights for the condition variable, follow the pattern of effects observed for cumulative learning (see Tables 5.5 and 5.6). There were two cases in eleven of a significant, positive treatment effect on posttest scores for common objectives; there was one instance in six of a significant, positive treatment effect on immediate learning. But the simplified regression models in Table 5.14 clearly indicate that a sizeable point difference separated the TICCIT and lecture conditions. The TICCIT program had a positive effect of over two points on students' immediate learning in four cases, and such an effect is equivalent to ten percent of the total possible score on topical tests.

Achievement Results: Analysis for Immediate Learning
Alexandria and Phoenix
Math Courses
Academic Year 1975-76

Course	Term	Dependent Variable	Number of Students	Multiple Correlation	Independent Variables	Regression Weights	Value of t-statistic
Math 007	Spring Semester	Topical Test Linear Equations (Form 607)	72	.71	TICCIT(1)/Lecture(0)	2.76	3.16^{**}
					Pretest	.23	6.03^{***}
					Constant	5.54	
Math 108	Spring Semester	Topical Test Algebraic Expressions (Form 608)	47	.60	TICCIT(1)/Lecture(0)	2.27	1.42
					Pretest	.25	4.54^{***}
						6.69	
Math 31	Fall Quarter	Topical Test Linear Equations (Form 617)	63	.62	TICCIT(1)/Lecture(0)	.41	.35
					Pretest	.24	5.98^{***}
					Constant	5.73	
Math 31	Winter Quarter	Topical Test Linear Equations (Form 617)	47	.63	TICCIT(1)/Lecture(0)	2.17	1.83
					Pretest	.27	5.08^{***}
					Constant	3.38	
Math 31	Spring Quarter	Topical Test Linear Equations (Form 617)	27	.75	TICCIT(1)/Lecture(0)	2.61	1.61
					Pretest	.22	4.75^{***}
					Constant	6.81	
Math 32	Spring Quarter	Topical Test Algebraic Expressions (Form 608)	52	.30	TICCIT(1)/Lecture(0)	-2.09	-1.61
					Pretest	.39	1.88
					Constant	12.88	

$^{**}p<.01$

$^{***}p<.001$

Table 5.14

This prevalent, positive impact of the TICCIT program provides an important piece of evidence about student achievement. Posttesting was dependent on course completion, and any analysis based on the posttests would be susceptible to doubt given the discrepancies in course completion by condition. But topical testing took place earlier in math courses, and its results apply to a wider range of students. The relevant population would be students capable of making progress toward course completion on the TICCIT system. Although the population is still not the same as all students enrolled for a course, it is a less restrictive one than that capable of completing a math course under the TICCIT program. And for this population the estimated treatment effects were predominately positive and of appreciable size.

Table 5.15 presents the analyses for retention. There was one significant treatment effect and it was negative. Indeed, the two slightly positive estimated effects together with the negative effect seem to contradict other results for student achievement. But often students began a more advanced course on the TICCIT system while completing its prerequisite course. They might then take a course-specific test for retention prior to studying the mathematical rules and concepts covered in the test. There were at least five students, for example, who started Math 106 while finishing Math 007. Such cases naturally interfered with our testing for retention and may invalidate these particular results.

5.3.d Estimated Treatment Effects

Table 5.16 gives a summary of the treatment effects estimated for student achievement. All of these estimates refer to point differences in posttest performance between students completing a course under the TICCIT program and similar students in lecture-discussion classes. There were significant

Achievement Results: Analysis for Retention
Alexandria and Phoenix
Mathematics Courses
Academic Year 1975-76

	Math 31 to Math 32		Math 007 to Math 106		Math 106 or 108 to Math 117	
Number of Students	N = 44 (13 TICCIT)		N = 83 (17 TICCIT)		N = 26 (15 TICCIT)	
Multiple Correlation	R = .49		R = .50		R = .71	
Standard Error of Estimate	$se_{est} = 2.54$		$se_{est} = 2.61$		$se_{est} = 1.88$	
Independent Variables	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic	Regression Weight	Value of t-statistic
Condition:						
TICCIT(1)/Programmed(-1)/Lecture(0)	.06	.11				
Lecture(1)/Programmed(-1)/TICCIT(0)	- .45	- .82				
TICCIT(1)/Lecture (0)			.55	.78	-1.81	-2.17^{*}
Entrance Ability:						
Pretest	.11	3.16^{**}	.14	5.07^{***}	.18	4.45^{***}
Term:						
Fall to Winter(1)/Winter to Spring(0)	.05	.06				
Fall to Spring(1)/Spring to Summer(0)			-1.05	-1.44		
Previous Courses:						
Math 106(1)/Math 107(0)					-2.34	-2.63^{*}
Constant:	11.51		9.02		7.82	

$^{*}p < .05$

$^{**}p < .01$

$^{***}p < .001$

Table 5.15

Estimated Treatment Effects on Student Achievement

College	Term	Course	Effect ($\hat{\tau}$)	t-Statistic	Population
Phoenix	Fall & Spring 1975-76	Math 007	- .07	- .14	Students in Day TICCIT Classes
		Math 007	5.40	2.69**	Students in Evening TICCIT Classes
	Spring & Summer 1976	Math 106	3.37	2.07*	Students in TICCIT Classes
		Math 108	.97	.43	Students in TICCIT Classes
		Math 117	-1.74	-1.13	Students in Day TICCIT Classes
		Math 117	6.14	2.05*	Students in Evening TICCIT Classes
	Spring 1976	English 19, 29	$.20^{e}$	1.42	Students in TICCIT Classes
		English 19, 29	2.38°	2.48*	Dependent on Age
	Fall 1976	English 19	$.08^{e}$	.68	Students in TICCIT Classes
		English 29	$- .50^{e}$	-3.03**	Students in TICCIT Classes
		English 19, 29	1.68°	2.41*	Students in TICCIT Classes
Alexandria	Fall, Winter & Spring 1975-76	Math 31	4.40	3.24**	Students in Day TICCIT Classes
		Math 31	- .11	- .06	Students in Evening TICCIT Classes
	Winter & Spring 1976	Math 32	4.31	2.15*	Students in TICCIT Classes
	Winter 1976	English 111	$.23^{e}$	1.00	Students in TICCIT Classes
		English 111	$- .93^{\circ}$	- .68	Students in TICCIT Classes
	Spring 1976	English 111	$-.16^{e}$	-1.17	Students in TICCIT Classes
		English 111	-2.21°	-1.96*	Dependent on Ability
	Fall 1976	English 111	$- .14^{e}$	- .89	Students in Day TICCIT Classes
		English 111	$.42^{e}$	2.11*	Students in Evening TICCIT Classes
		English 111	$- .90^{\circ}$	-1.14	Students in TICCIT Classes

^{e}Effect on essay posttest.

$^{\circ}$Effect on objective posttest.

*p < .05

**p < .01

Table 5.16

positive effects in five math courses of six. But these effects became evident only when analyses encompassed data from multiple academic terms. Otherwise the arbitrary time constraints of a single term precluded the use of posttests taken after the formal close of the term, and many students on the TICCIT system chose to take advantage of its self-paced feature by continuing a course beyond a term's end. There were also significant, positive effects on the objective posttest of writing skills. These occurred in both the spring and fall semesters at Phoenix. However, study on the TICCIT system as an adjunct to traditional classroom practices led to a significant negative effect on the objective posttest for English 111 in the spring quarter.

To some extent the significant effects reflect the context of the demonstration as well as outcomes of the TICCIT program. The sizeable point differences observed in Math 007 and Math 117 occurred in the evening division. That was when regular faculty members supervised students on the TICCIT system while primarily part-time instructors taught the lecture sections of math courses. The significant negative effect found in English 029 in the fall semester was also related to staffing. Part-time instructors were responsible for both TICCIT and lecture-discussion classes. But those instructors given TICCIT classes were unfamiliar with the program and assigned too late to receive an adequate orientation to its coverage and structure. The positive impact on essay test performance, $\hat{\tau}$ of .42 for English 111 in the fall quarter, might also be attributed to differences among instructors rather than programs. There was an instructor in the evening division who stressed writing skills, and whose lecture-discussion class had low essay scores relative to other lecture-discussion classes and TICCIT classes. Since students from this class constituted nearly half of the lecture-discussion comparison group, their essay performance was enough to make a TICCIT effect apparent in the evening. Across day and evening classes, however, the estimated treatment effect would not be significant, $\hat{\tau} = .06$ and $t = .53$.

Even if we were to disregard all significant effects somehow linked to particular facts about the context of the demonstration, there would still be six other cases. The positive impact of the TICCIT program on student achievement in math appears in Math 106, Math 31 and Math 32. The positive impact of the TICCIT program on student achievement in English appears in scores on the objective test of writing skills: significant effects were evident in English 019 and English 029 for both the spring and fall semesters. However, there was a significant negative effect in English 111 that became more pronounced for students of lower entrance ability. This estimated treatment effect comes from the spring quarter, the one quarter for which there had not been a significant negative effect on course completion for English 111 and the completion effects that had occurred in the winter and fall quarters also varied according to entrance ability (see Table 4.9).

This raises a critical question for which there is really no adequate answer: Does the negative TICCIT impact on course completion make favorable outcomes more likely for other aspects of student performance? Since the TICCIT program acted to select only certain students for posttesting, it may be that characteristics other than those included in the achievement analyses distinguished students in the TICCIT condition from those in the lecture condition. Then such characteristics might explain differences in posttest performance seemingly attributable to the treatment. For example, the negative impact on course completion found across academic terms (see Table 4.8) might account for differences in student performance on the objective posttest in English 019 and English 029.

The pronounced differences by condition in math completion rates (see Tables 4.2 and 4.3) make the selective nature of the TICCIT program an attractive interpretation for the achievement results. But other data tend to support acceptance of the positive treatment effects as program outcomes. Testing achievement in particular topics revealed a positive TICCIT impact at stages in math courses prior to posttesting (see Table 5.14). Yet data from posttesting all students in Algebra I and Algebra II, regardless of their anticipated course grades, indicated a negative TICCIT effect. Comparisons of students attending math classes toward the close of a quarter resulted in these estimates: $\hat{\tau} = -4.93$ and $t = -4.34$, $p < .001$ for Math 31 in the fall quarter; $\hat{\tau} = 2.30$ and $t = 1.18$ for Math 31 in the winter quarter; $\hat{\tau} = -3.80$ and $t = -1.59$ for Math 31 in the spring quarter; and $\hat{\tau} = -1.35$ and $t = -.99$ for Math 32 in the winter and spring quarters. These comparisons do incorporate a bias, however, in the nature of the groups posttested in each condition. Students still attending lecture classes were those completing a math course while students from TICCIT classes were primarily those making slow progress in a math course. With such comparison groups a negative estimate of TICCIT's effects should be expected.

It is perhaps easier and more appropriate to accept the estimates given in Table 5.16 for what they represent. Each estimate of a treatment effect reflects a point difference in posttest performance between students who completed a course under the TICCIT program and similar students from lecture-discussion classes. Similarity was determined by entrance ability as well as demographic characteristics. Our definition of similarity perhaps omitted a critical variable, but we remain uncertain about what it might be and how it might be measured.

5.4 Discussion

The TICCIT program had a positive impact on student achievement. Students capable of completing a course under the TICCIT program generally attained higher posttest scores than those reached by similar students under conventional teaching methods. These results were evident in those applications of the TICCIT program closest to the developers' concept of mainline instruction. But such applications had also led to pronounced differences in course completion rates unfavorable to the TICCIT program.

It might be appropriate to consider whether the favorable achievement differences offset the negative TICCIT impact on course completion. The significant point differences in math courses often exceeded ten percent of the total score possible on a posttest and corresponded to approximately two-thirds of a standard deviation on the test. This was the case in the beginning algebra courses as well as the more advanced algebra courses offered on the TICCIT system. But even greater achievement differences would not balance the discrepancies between conditions in their completion rates for math courses. A five point advantage in posttest scores hardly seems worth a drop in completion rates to half of the rate attainable through conventional practices. Perhaps the positive achievement effects found in math courses represent the promise of the TICCIT program, but only promise for applications with learners capable of independent study or under circumstances where an outcome like completion would not be a factor.

The achievement results obtained in English courses suggest a different conclusion. Adjunctive use of the TICCIT program, even carefully integrated with classroom practices, led to significant negative effects on either course completion or student achievement. The estimated size of these effects varied according to students' entrance ability. Students with lower pretest scores stood to lose more as a result of exposure to the TICCIT program instead of traditional instruction. Conversely, a select group of students with high pretest scores benefitted from working on the TICCIT system. But use of the TICCIT program as a supplement to classroom teaching failed to demonstrate the same consistency of positive achievement effects found in math courses.

It was with a mainline application of the TICCIT program to instruction in English composition that positive achievement effects began to balance negative completion effects. There were consistent and statistically significant point differences on the objective test of writing skills. They occurred when students studied the fundamentals of English on the TICCIT system. Often instruction was supplemented by small group discussions about common difficulties in learning English fundamentals as well as writing assignments. Instructors took an active role in prescribing material for study, leading group discussions, and handling individual student problems. Even student performance on essay tests was better in the TICCIT condition, except when part-time instructors unfamiliar with the TICCIT program conducted TICCIT classes. These achievement results not only show promise for the TICCIT program but raise hopes that an improved program would yield completion rates at least comparable to lecture-discussion instruction and achievement outcomes still better than those from this evaluation.

Finding positive treatment effects on test performance in English surprised us. Prior studies of computer-assisted instruction, especially at the college level, suggest that this teaching method might benefit highly structured subject fields. But perhaps that structure also acts as a deterent to student progress in a self-paced system. A subject less well defined might be conducive to greater teacher participation and more realistic expectations of computer capabilities for teaching. Without a definite structure to the subject matter there is also opportunity for student choice and teacher direction. And the rigor of developing computer curricular materials would probably be beneficial in forcing specificity and structure on teaching ill-defined subjects. Perhaps we should pursue techniques like computer-assisted instruction for teaching in the humanities, social sciences and other similar fields with as much energy and excitement as usually devoted to disciplines known for their structure.

Besides the arguments already set forth as alternative interpretations of our estimated treatment effects, there is another plausible explanation that deserves mention. Tobias (Tobias, 1976; Tobias & Ingber, 1976) reviewed attempts to adapt instruction to individual differences. He concluded that students with less prior familiarity of the subject matter, or lower entrance ability, need more instructional support. This view of achievement-treatment interactions fits well with the results of our evaluation. It would be consistent with the selective nature of the TICCIT program in math courses: students weak in entrance ability failed to satisfy course requirements within an academic term while students strong in prior familiarity completed the course and did well on posttests. Interactions between pretest score and instructional condition did come into our regression models for completion or achievement in English courses. The TICCIT program may provide instructional support sufficient for students of strong entrance ability but inadequate for others. Accepting achievement-treatment interactions as a viable interpretation of results would also imply that our analyses included the key student characteristic in identifying similar students, namely entrance ability.

Subject to achievement-treatment interactions, the TICCIT program succeeded in improving student achievement. Students who completed courses under the TICCIT program generally attained higher posttest scores than comparable students did in lecture-discussion classes. This effect was observed among those students better prepared for their mathematics or English courses in terms of their prior familiarity of the subject matter. While such students may constitute a small percentage of the community college's total enrollment, especially for courses in mathematics, they might be a majority of the learners in another context. At industrial or educational institutions which screen and select applicants on a competitive basis, the TICCIT program could result in uniform positive effects on achievement.

Chapter 6

Student Attitudes

Over the last decade there has been a dramatic increase in the role of student attitudes in evaluating courses. Colleges now actively solicit student reactions to their courses and instructors through the routine administration of questionnaires. Students' reactions to their courses have become an important factor in considering curriculum changes, and their ratings of instructors influence decisions about faculty appointment. Despite the rise in the recognition of student attitudes as a legitimate concern in instruction, curriculum evaluations often neglect this aspect of student performance. Yet we can assess attitudes across instructional conditions and make comparisons of program results.

Such comparisons seem especially appropriate in evaluating computer-assisted instruction. Much of the interest in this technique evolved from its promise for tailoring instruction to each individual student. Computer-assisted instruction would presumedly enable students to learn at a pace consistent with their ability and readily adapt to the needs of students. So students should prefer learning on computers to the teaching in classrooms. Research results indeed support this interpretation: There is an abundance of studies showing positive student attitudes toward computer-assisted instruction (e.g., Brown & Gilman, 1968; Mathis et al, 1970; Smith, 1973; Summerlin, 1971). But these deal with other computer systems and concern students at other levels of education. We sought to document student reactions to the TICCIT program at community colleges, and to evaluate these affective results in relation to the reactions of similar students in lecture-discussion sections of the same courses.

This chapter addresses student attitudes as a third dimension of student performance. The first section specifies the student population for the analysis of attitude results; it also presents an explanation of the measures that define student attitudes for our evaluation. The second section presents summaries of the attitude data. These summaries reflect both students' scores on the overall attitude scale and their responses to specific statements on the attitude survey. Analyses of the attitude data and estimates of treatment effects appear in the third section of this chapter. Like the analyses for student achievement which concentrated on posttest items reflecting objectives held in common across instructional conditions, the analyses here focus on those survey statements that were identical or closely parallel in TICCIT classes and lecture-discussion sections. The final section is a discussion of the attitude results and their possible implications.

6.1 Students and Attitudes

As with course completion rates and student achievement, evaluating the impact of the TICCIT program on student attitudes depended on drawing contrasts across comparison groups. Students' attitudes toward courses taught in a conventional manner served as relative standard against which we could estimate TICCIT effects. In both TICCIT classes and lecture sections students responded to a survey about their course. They gave their judgments of the course and their reactions to its instruction. However, instruction provided by teachers and instruction conducted by computers may be quite different. The attitude surveys, like the achievement posttests that reflected objectives held in common across conditions, focused on those aspects of a course which appeared in lecture sections as well as in TICCIT classes.

The estimated treatment effects presented here may seem unfamiliar. Although evaluations frequently define a program's impact on achievement as a number of points on a test, the same approach is seldom applied to the problem of assessing attitudes. But attitudes represent another component of student performance which may be affected by a program. Computer-assisted instruction especially may appeal to students for its innovative delivery of instruction tailored to the individual learner. We applied the same procedures to evaluating course completion rates, student achievement, and student attitudes. This meant that the same degree of care had to be devoted to defining student populations and to developing fair bases for comparisons.

6.1.a Population of Students

Students responded to our attitude survey upon completing a target course in mathematics or English. This practice in itself restricted the population of respondents in each comparison group. It has already been shown that there were differences in program outcomes according to the criterion of course completion. Generally, one-half to two-thirds of the students enrolled in lecture sections of target courses completed all course requirements within an academic term. A lower proportion of the students enrolled for the same courses under the TICCIT program actually finished their studies within an academic term and received college credits for the course. These lower completion rates were particularly evident in math courses and also apparent in English courses. Yet those students who did successfully complete a course under the TICCIT program attained higher posttest scores than comparable students in lecture sections. How do these results affect inferences about student attitudes? An answer lies in the student population for which we may draw inferences.

The procedures for estimating treatment effects take discrepancies in course completion rates into account. Consider what a treatment effect represents: it stands for the difference between the attitudes expressed by a student completing a course under the TICCIT program and the attitudes that the same student would probably hold in a lecture section. Given the responses of students from TICCIT classes, the responses of similar students in lecture sections become the best available estimates of how TICCIT students would react in the lecture condition. Statistical procedures start with the population of students who completed courses under the TICCIT program and responded to our attitude survey, and the procedures yield estimated treatment effects that apply only to this population.

To a great extent the strength of our analyses rests with the definition of student similarity across conditions. When student achievement is the criterion, achievement pretests and demographic characteristics provide an adequate definition of student similarity. The multiple correlations for the achievement analyses, usually in the neighborhood of .60 and sometimes above .70, attest to the usefulness of these variables in identifying the lecture counterparts to students who had completed courses under the TICCIT program. However, there was no instrument that would fulfill the role of an achievement pretest when examining student attitudes. Pilot trials with brief surveys of students' predispositions toward computer-assisted instruction had convinced us that such attitude pretests were too susceptible to suggestions made in orientation sessions and too unreliable. Students had little prior exposure to computers from which they might form initial opinions. In finding students from lecture sections comparable to those who had completed TICCIT classes, we relied on the same set of variables in the attitude analyses as in the achievement analyses.

This consistency in the approach taken to data analysis should not be regarded as an implication of the dependence of attitude results on achievement results. That student achievement improved under the TICCIT program is a separate finding, and any statement of attitudinal impact stands apart from it. However, our estimates of treatment effects for these two components of student performance do refer to the same population: those students capable of completing a course under the TICCIT program. Only for this group of students should the treatment effects, both those on student achievement and those on student attitudes, be regarded as representative.

6.1.b Measures of Attitudes

Statements on the student survey and scales formed from responses to particular statements really define what student attitudes meant within the context of this evaluation. Responses to an attitude survey, unlike answers to an achievement posttest, possess no absolute right or wrong key. They do indicate direction as each response to a statement may be taken as falling on a continuum of negative to positive affect. Whether stronger agreement with a statement indicates a more or less positive attitude toward the TICCIT program would depend on the phrasing of the particular item stem. Moreover, the estimated treatment effects represent differences of degree: How positive or negative were students' reactions to a course under the TICCIT program in relation to student attitudes toward that course in a lecture-discussion format?

Student Survey. The student attitude survey was meant to solicit reactions and opinions about the instruction provided in a course (see Appendix F). Emphasis naturally fell on aspects of the TICCIT program and their parallels in traditional classes. There were statements about the features of learner control built into the TICCIT system (e.g., items 7-11 and 13 on Form 035), about student participation in the process of learning (e.g., items 1, 5, 14 and 16 on Form 035), and about instruction tailored to the individual student (e.g., items 2, 3, 6 and 18 on Form 035). Some of these questions had been adapted from other instruments dealing with students' attitudes toward computer-assisted instruction (Brown, 1966) or with students' ratings of college teachers (Centra, 1972). Most questions were developed especially for this evaluation so as to cover specific features and possible advantages or disadvantages of the TICCIT program.

Response Format. Each item stem intended to solicit student attitudes has a five-point response scale. Students could indicate their extent of agreement, from strong agreement coded as five points to strong disagreement coded as one point, with an item. Thus the maximum score possible for 20 items, for example, would be 100 points, and this would reflect a highly enthusiastic, positive attitude. Because some item stems had been phrased in a negative manner (e.g., "The method of instruction for this course was too impersonal for me") in order to discourage the simple repetition of the same response across all items, responses to these statements had to be reversed in assigning scores. Only those statements on the attitude survey with a clear direction, whether positive or negative, entered into attitude scores.

It was possible that students would react favorably to certain components of a course under the TICCIT program and unfavorably to others. A simple total for an attitude score would fail to reveal such distinctions. By conducting factor analyses of the attitude data, we identified the major dimensions underlying students' reactions to courses under the TICCIT program. Since these dimensions would become the basis for comparisons of results, we studied responses to the statements that appeared both on the survey given in TICCIT classes and on the survey given in lecture sections.

Factor Analyses. Each factor analysis dealt with an item intercorrelation matrix. An item was included in that matrix if its stem had a definite direction and if it appeared on the surveys for both the TICCIT and lecture conditions. The student survey administered in mathematics courses under the TICCIT program in the fall term of the 1975-76 academic year (Form 035 in Appendix F) had a total of 35 questions. Twenty-nine of these questions (items 1-29) were actually statements accompanied by a five-point response scale; the other questions really pertained to student activities. Seven of the statements (items 2, 5, 7, 15, 21, 23 and 25) had no direct counterpart in the lecture condition, and four statements (items 26-29) had no obvious direction but instead solicited information from the student's perspective. This left 18 items to be examined through factor analysis. A revision of the student survey for mathematics courses led to the addition of another item in the form for the second-half of the 1975-76 academic year (item 15 in Form 069). There were, therefore, 19 items in the intercorrelation matrix for that factor analysis. The student survey employed in English courses included the same statements, referring to English rather than mathematics courses, as well as two items adapted from an instructor's own questionnaire (items 16 and 17 on Form 068). All of the item stems considered in the factor analyses appear in Table 6.1.

The three factor analyses presented in Table 6.1 correspond to the three forms of the student survey administered in the demonstration period. The first analysis was conducted for the survey distributed to students in mathematics courses under the TICCIT program in the fall term of the 1975-76 academic year (Form 035). For the remainder of that academic year students

Student Attitudes in Courses under the TICCIT Program

Varimax Primary Factors

Item Number				Mathematics Courses Fall 1975-76 (N = 126) Factors			Mathematics Courses Spring 1975-76 (N = 159) Factors		English Courses Spring, Fall 1976 (N = 140) Factors		
Form 035	Form 069	Form 068	Stem	A-I	A-II	A-III	B-I	B-II	C-I	C-II	C-III
1	1	1	In this course I felt free to ask questions		74			63			55
3	3	3	I received a lot of individual attention from instructors		75			82			80
4	4	4	The instructor(s) seemed genuinely concerned with my progress		77			77			66
6	6	6	Instruction in this class met my own particular needs	71[*]			65		52		
8	8	8	ADVICE helped me to progress through this course		63			57		62	
9	9	9	PRACTICE helped me in learning rules and concepts			80	63			66	
10	10	10	HELP provided clear explanations			70	71			75	
11	11	11	RULE made concepts easy to learn			77	62			70	
12	12	12	Taking tests let me know whether I really understood the material					52			
13	13	13	EXAMPLE did not show me how to (solve problems/write well)				-50				
14	14	14	In this course I felt responsible for my own learning								
16	17	19	In this course I felt challenged to do my best work	59			69	59	50		
17	18	20	I was satisfied with my personal progress in this course	69			64				
18	19	21	The method of instruction for this course was too impersonal	-59			-69		-59		
19	20	22	My interest in (math/writing) has been increased by this course	67			54		50		
20	21	23	I would recommend this course to my friends	76			62	57	56		
22	23	25	Time passed quickly while I was in class								
24	25	27	I tried to just finish the lessons rather than learn the material						-72		
	15	18	Other students in this section seemed to like the course								
		16	I learned a lot about grammar in this course						58		
		17	I learned a lot about writing in this course						57		

[*] Only entries above .49 appear in this table. Decimal points have been omitted.

Table 6.1

in TICCIT classes for math courses responded to a revised form of the survey (Form 069), and these data formed the item intercorrelation matrix for the second factor analysis. A third analysis was conducted for the survey (Form 068) given in English courses on the TICCIT system, but only for courses consistent with the concept of mainline instruction.

The item intercorrelation matrix for each of these survey forms was subject to a principal components analysis with varimax orthogonal rotations. In each analysis a break in the magnitude of the latent roots determined the number of factors to be rotated. Three factors were retained for rotation in the analysis for the student survey distributed in mathematics courses in the fall term, labeled as Factors A-I, A-II and A-III in Table 6.1. The eigenvalues associated with these factors were 6.40, 1.66 and 1.31, respectively. The two factors shown in the varimax solution for the student survey used in mathematics courses in the second-half of the 1975-76 academic year, Factors B-I and B-II, had eigenvalues of 7.15 and 1.46. The analysis of the survey given in English courses revealed three factors, Factors C-I, C-II and C-III, with eigenvalues of 6.01, 1.79 and 1.56, respectively. These varimax solutions, then, accounted for nearly 50% of the total variance in each intercorrelation matrix. The solutions themselves appear in Table 6.1 and suggest three dimensions of students' attitudes toward courses under the TICCIT program.

Dimensions. Across academic terms and courses there is a remarkable consistency to the factor structure shown in Table 6.1. The items which loaded highest under Factor A-I can also be found grouped together under Factors B-I and C-I. There is nearly complete overlap among Factors A-III, B-II and C-III. And the statements under Factor A-III also appear under Factors B-I and C-II. These three dimensions reflect important components of students' attitudes toward a course: the student's personal satisfaction with the course as a whole; the student's perception of the individual attention given to him or her; and the student's reactions to specific features of the TICCIT system.

The statements under Factor A-I relate to a student's personal satisfaction with a course on the TICCIT system. These items concern whether the student would recommend the course to friends, the extent to which instruction met the student's own particular needs, the degree of satisfaction a student felt with his or her personal progress in the course, and the extent to which the course increased the student's interest in the subject matter. Other statements shown under this factor refer to the challenge posed by a course and the impersonal nature of instruction. All of these item stems appear together in analyses corresponding to mathematics courses in the fall term of 1975-76 (Factor A-I), mathematics courses in the remainder of that academic year (Factor B-I), and English courses in the 1976 calendar year (Factor C-I). Additional statements on students' own estimates of the amount they had learned in a course (items 16 and 17 on Form 068) also loaded on Factor C-I. This factor consistently had the highest eigenvalue: it explained the largest proportion of total variance. Because it reflects a student's evaluation of a course in terms of his or her own progress and needs, this dimension seems to be critical for any assessment of student attitudes. The items under this factor formed the scale called Course Satisfaction in our analyses of TICCIT effects on student attitudes.

Factor A-II includes those statements relevant to the individual attention that students received in a course. The two items with the highest entries under this factor, whether interpreted as shown under Factor A-II, B-II or C-III, pertain to the individual attention given by instructors (item 3) and their concern with a student's course progress (item 4). Often such individual attention came into play when students raised questions about the subject matter presented on the TICCIT system or asked about procedures for operating the TICCIT system (see Chapter 7: Student Activities). Instructors or proctors would respond to these student requests for assistance. Thus, it is consistent with the affective dimension represented by Factor A-II that a statement about students' comfort in asking questions (item 1), questions which in turn elicited individual attention, also has a high entry. Even a statement about the individual attention which students received from the TICCIT system (item 8), TICCIT's comments, attention is based on interpersonal contact. This factor became a second scale, Individual Attention, for our analyses of affective impact.

The third dimension of student attitudes covers students' reactions to specific features of the TICCIT system. Factor A-III consists of items related to the learner-control options called PRACTICE, HELP and RULE (items 9, 10 and 11). In the factor analysis conducted for attitudinal data from English courses, a parallel factor includes an additional statement about the ADVICE feature. The appearance of this statement under Factor C-II rather than Factor C-III seems to indicate the instructor's prominent role in English courses on the TICCIT system: students viewed instructors as the primary source of the individual attention given to them and considered ADVICE to be another system feature. On the other hand, students in mathematics courses on the TICCIT system in the second-half of the 1975-76 academic year tended to react to their courses as a direct reflection on the TICCIT program. Their personal satisfaction with a course was closely related to their reactions to specific system features: Factor B-I reflects statements on both of these dimensions of student attitudes, and Factor B-II suggests that students attributed individual attention to the computer system's ACVICE as well as its online mastery tests. Students in these mathematics courses relied heavily on the TICCIT program and viewed their courses very much as a function of specific system features. System Features was the third scale studied in our analyses of student attitudes.

The scales that define student attitudes for the purposes of our evaluation were constructed in accordance with the dimensions revealed by factor analysis. Students' responses to statements posed in both TICCIT classes and lecture sections of a course gives us a basis for determining the affective impact of the TICCIT program. Beyond the overall effect evident from a total score on such statements, we will examine student attitudes in terms of key dimensions: Course Satisfaction, Individual Attention, and System Features. Reliability estimates for these scales appear in Chapter 2: Methods and Measurement, and a complete list of the statements included in each scale can be found in Appendix R. Whatever the source or size of the estimated treatment effects on student attitudes, it should be kept in mind that the effects apply to those students who completed courses on the TICCIT system.

6.2 Presentation of Results

Descriptive statistics for student scores on the attitude survey appear in Appendix Q. These summaries report the number of observations within each section of a course, mean scores on all attitudinal statements, mean scores on those statements posed in both the TICCIT and lecture conditions, and the standard deviations of these scores. The appendix gives these figures for each section of a target course as well as the totals for all sections within an academic term broken down by instructional condition.

Two general patterns emerge from these data for sections of mathematics courses. Across courses and academic terms it seems that students in TICCIT classes for mathematics, when offered with a high student-teacher ratio as had been the case at Phoenix College, had less positive attitudes toward their courses than did students in traditional lecture classes. Those sections with the lowest mean scores on common statements were usually the classes on the TICCIT system. Yet TICCIT classes also showed the highest standard deviations, suggesting a wider range of student reactions and greater differences among individual students. This is almost the exact opposite of the pattern of achievement results in these same courses. On that component of student performance the highest means and lowest standard deviation had occurred in TICCIT classes.

A second pattern was evident from the attitude results in a mathematics course that had been offered under three conditions. Those sections of Algebra I conducted under programmed instruction had the highest mean scores among all classes. The mean score on statements common across conditions was higher in sections with programmed instruction than in classes on the TICCIT system or in lecture sections. But these attitude scores include every respondent to the survey regardless of that student's final grade. Of an initial enrollment of 161 students in sections under programmed instruction there were just 31 students who completed the course requirements for Algebra I in the 1975-76 academic year. It had been our intention to restrict comparisons to those students who completed a course. Otherwise it would be difficult to specify the student population to which the estimated treatment effects applied and to collect appropriate attitude data. Responses from students in lecture sections, then, seemed a much better standard for gauging the attitude results of the TICCIT program.

There was no consistent pattern of attitude results among sections of English courses. Sometimes the highest mean score on common statements occurred in a section on the TICCIT system. Often the lowest mean score for the same course and academic term also occurred in another section on the TICCIT system. Extreme section averages were as frequent in lecture-discussion sections. In themselves the attitude results across course sections illustrate the substantial variation in student reactions from section to section. A full standard deviation separated the highest and lowest mean scores in both mathematics and English courses.

6.2.a Common Statements

The student surveys contained over 20 statements phrased in an identical or closely parallel manner across instructional conditions. There were other statements on the survey specific to a particular condition or relevant to student activities. But the statements that appeared regardless of condition formed the basis for our comparisons of attitude results. Most of these statements had an obvious direction, so stronger agreement with a positive item stem or stronger disagreement with a negative item stem clearly implied an increasingly positive student reaction. Reversing responses to negative stems enabled us to calculate an attitude score on common statements. There were also four statements on each form of the student survey that had no definite direction. These item stems solicited students' opinions about the pace, difficulty and work load of a course.

Scores. Tables 6.2 and 6.3 present the attitude scores on common statements. Of the eleven cases presented in Table 6.2 there were nine instances in which student attitudes toward mathematics courses under the TICCIT program were less positive than the reactions given in lecture sections. Furthermore, these lower attitude scores occurred across academic

Attitude Summary
Mathematics Courses
Academic Year 1975-76

College	Course	Term	Comparison Group	N	Number of Items	Mean	sd
Phoenix	Math 007	Fall	TICCIT	27	18	64.07	14.5
			Lecture	134	18	69.78	9.8
		Spring	TICCIT	20	19	67.60	16.2
			Lecture	121	19	74.31	11.3
	Math 106	Fall	TICCIT	20	18	63.10	12.1
			Lecture	73	18	71.05	9.1
		Spring	TICCIT	11	19	68.36	12.1
			Lecture	81	19	74.56	9.6
	Math 108	Fall	TICCIT	11	18	63.82	14.9
			Lecture	38	18	74.00	9.0
		Spring	TICCIT	15	19	69.40	12.5
			Lecture	37	19	76.84	8.1
Alexandria	Math 31	Fall	TICCIT	46	18	71.59	11.2
			Programmed	21	18	75.05	10.4
			Lecture	44	18	71.64	10.4
		Winter	TICCIT	64	19	76.56	10.2
			Programmed	36	19	80.89	9.0
			Lecture	23	19	74.26	10.1
		Spring	TICCIT	24	19	71.17	12.5
			Programmed	38	19	80.21	9.8
			Lecture	12	19	73.75	9.6
	Math 32	Winter	TICCIT	22	19	66.45	12.5
			Lecture	20	19	76.90	13.6
		Spring	TICCIT	18	19	71.44	8.6
			Lecture	30	19	76.23	9.4

Table 6.2

Attitude Summary
English Courses
Calendar Year 1976

College	Course	Term	Comparison Group	N	Number of Items	Mean	sd
Phoenix	English 19	Spring	TICCIT	15	21	87.80	9.0
			Lecture	49	21	83.12	12.7
		Fall	TICCIT	73	21	86.33	10.1
			Lecture	130	21	80.42	12.2
	English 29	Spring	TICCIT	27	21	85.74	9.3
			Lecture	31	21	85.55	11.9
		Fall	TICCIT	37	21	84.59	8.8
			Lecture	48	21	81.38	11.9
Alexandria	English 111	Winter	TICCIT	56	21	74.66	13.6
			Lecture	54	21	80.17	12.1
		Spring	TICCIT	81	21	78.84	11.7
			Lecture	161	21	83.01	11.6
		Fall	TICCIT	117	21	73.86	12.1
			Lecture	75	21	82.31	12.6

Table 6.3

terms in four math courses and only one math course showed mixed results across terms. Such replications of attitude results certainly suggest that students favored conventional sections over TICCIT classes of mathematics courses. That the magnitude of the difference in mean scores was most often greater than one-half of a standard deviation tends to support this interpretation. But descriptive statistics do not prove the veracity of any conclusion. Since students who completed mathematics courses under the TICCIT program also had quite different pretest scores when compared to those of students from lecture sections, the disparity in attitude scores may be attributed to dissimilarities in the comparison groups. A better estimate of treatment effects on student attitudes will come from an analysis which takes student similarity into account.

The attitude results in English courses suggest both positive and negative TICCIT effects. Courses which relied heavily on the TICCIT system for instruction in the fundamentals of English, English 19 and English 29, show higher attitude scores among students in sections that spent considerable amounts of time on the TICCIT system. The opposite directions of these differences hardly contradict each other. They instead indicate that differences in a course's coverage, in the manner of applying the TICCIT program, or perhaps in the colleges themselves can exert a strong influence on the nature of impact on student attitudes.

Item Responses. Where attitude scores suggest that students' reactions to a course depended on its instructional condition, responses to individual statements may reveal what led students to react less favorably or more positively to a course under the TICCIT program. The TICCIT program seemed to result in less favorable attitudes in most mathematics courses and in more positive attitudes in certain English courses. Tables 6.4 and 6.5

detail student responses to individual statements on the attitude survey in order to illustrate these apparent negative and positive effects. Appendix R contains summaries of item responses for all target courses in the project.

Table 6.4 has response means and standard deviations for mathematics courses. This particular academic term, the fall semester of the 1975-76 academic year, marked the start of the demonstration phase of the project. These courses involved the use of the TICCIT program as the primary instructional resource available to students; student-teacher ratios in TICCIT classes were above those in traditional lecture sections. By themselves the mean responses to statements may appear to be positive and representative of a favorable attitude. Students tended to agree with those item stems phrased in a positive manner and to disagree with statements worded in a negative direction. Students who completed math courses under the TICCIT program did not react negatively to their courses but their attitudes were less positive than those expressed by students from lecture sections. Nearly every statement shows a less positive mean response among students from the TICCIT classes when compared against the mean response among students from lecture sections.

Table 6.5 contains attitude data drawn from English courses. These responses came from students in courses offered in the last academic term of the demonstration, the fall term of the 1967-77 academic year, and these courses had heavier instructor involvement in those sections in the TICCIT system. The subject matter perhaps required greater teacher participation; it also had a less formal structure than mathematics. Furthermore, the TICCIT curriculum in English had been developed after mathematics and so reflected some experience in courseware production. Again students tended to react favorably to their courses in that they agreed with the item

Student Attitude Survey:
Item Responses across Instructional Conditions
Phoenix College
Math 007, 106, and 108
Fall Semester, 1975

	TICCIT (N ≅ 64)			Lecture (N ≅ 260)		
Item Stems	**Item Number (Form 035)**	**Mean**	**sd**	**Item Number (Form 040)**	**Mean**	**sd**
Satisfaction subscore (6 items):						
I would recommend this course to my friends.	20	3.27	1.50	19	3.91	0.96
I was satisfied with my personal progress in this course.	17	3.27	1.25	16	3.50	1.21
Instruction in this class met my own particular needs.	6	3.43	1.37	14	3.99	0.91
My interest in math has been increased by this course.	19	3.08	1.35	18	3.55	1.06
The method of instruction for this course was too impersonal for me.	18	2.58	1.24	17	2.03	1.00
In this course I felt challenged to do my best work.	16	3.70	1.22	15	3.88	1.04
Attention subscore (4 items):						
I received a lot of individual attention from the instructor in this course.	3	2.89	1.30	2	3.53	1.17
The instructor seemed genuinely concerned with my progress.	4	3.40	1.21	3	3.85	1.03
In this course I felt free to ask questions.	1	4.09	1.07	1	4.71	0.54
TICCIT's comments on my work ("ADVICE") helped me to progress through this course./The instructor's comments on my work helped me to progress through this course.	8	2.52	1.22	12	3.33	1.05
Feature subscore (3 items):						
Doing practice problems ("PRACTICE") helped me in learning mathematical rules and concepts./Homework assignments helped me in learning mathematical rules and concepts.	9	4.29	0.82	10	4.25	0.85

Table 6.4(a)

Item Stems	Item Number (Form 035)	Mean	sd	Item Number (Form 040)	Mean	sd
TICCIT "HELP" provided clear explanations when the material was difficult to understand./The instructor provided clear explanations when the material was difficult to understand.	10	3.12	1.32	6	4.33	0.80
The rule statements ("RULE") on TICCIT made mathematical concepts easy to learn./The class lectures made mathematical concepts easy to learn.	11	3.59	1.06	4	4.16	0.86
Other common attitude stems (5 items):						
Taking tests in this course let me know whether or not I really understood the material.	12	3.59	1.26	7	4.02	1.03
Examples ("EXAMPLE") really did not show me how to solve problems./Examples from the textbook and lectures really did not show me how to solve problems.	13	3.00	1.27	8	2.07	1.06
In this course I felt responsible for my own learning.	14	4.28	0.85	9	3.79	1.05
Time passed quickly while I was in class.	22	4.43	0.79	20	3.85	1.13
I tried to just finish the lessons rather than learn the material.	24	2.14	1.33	21	1.91	1.07
Information statements:						
I wanted information that would tell me where I stood in comparison to other students.	26	2.00	1.29	22	2.51	1.38
For me, the pace at which I had to cover the material in order to finish the course was:/For me, the pace at which the instructor covered the material during the term was:	27	3.15	0.92	23	2.76	0.75
For my preparation and ability most of the work in this course was:	28	2.95	0.86	24	3.05	0.90
The work load for this course, in relation to other courses of equal credit, was:	29	3.48	0.88	25	2.89	0.81

Item Coding (Form 035):

(items 1-21)	(items 22-26)	(item 27)	(item 28)	(item 29)
5 = Strongly Agree	5 = Almost Always	5 = Very Slow	5 = Very Difficult	5 = Much Lighter
4 = Agree	4 = Frequently	4 = Somewhat Slow	4 = Somewhat Difficult	4 = Lighter
3 = Not Sure	3 = Not Sure	3 = About Right	3 = About Right	3 = About the Same
2 = Disagree	2 = Occasionally	2 = Somewhat Fast	2 = Somewhat Easy	2 = Heavier
1 = Strongly Disagree	1 = Almost Never	1 = Very Fast	1 = Very Easy	1 = Much Heavier

Table 6.4(b)

Student Attitude Survey:
Item Responses across Instructional Conditions
Phoenix College
English 19 and 29
Fall Semester, 1976

Item Stems	TICCIT (N ≅ 110) Item Number (Form 068)	TICCIT Mean	TICCIT sd	Lecture (N ≅ 177) Item Number (Form 065)	Lecture Mean	Lecture sd
Satisfaction subscore:						
I tried to just finish the assignments rather than learn the material.	27	1.64	.90	23	2.06	1.14
The method of instruction in this course was too impersonal for me.	21	2.36	1.05	19	2.34	.99
I learned a lot about grammar in this course.	16	4.13	.72	13	4.06	.98
I learned a lot about composition in this course.	17	3.97	.81	14	3.74	1.08
I would recommend this course [with TICCIT] to my friends.	23	4.15	.97	21	3.97	1.09
Instruction in this class met my own particular needs.	6	4.31	.76	16	3.85	1.01
In this course I felt challenged to do my best work.	19	4.24	.78	17	3.76	1.06
My interest in writing has been increased by this course.	22	3.54	1.01	20	3.45	1.12
Attention subscore:						
I received a lot of individual attention from the instructor in this course.	3	3.95	.87	2	3.54	1.20
The instructor seemed genuinely concerned with my progress.	4	4.35	.78	3	3.99	1.05
In this course I felt free to ask questions.	1	4.63	.63	1	4.42	.80
Feature subscore:						
TICCIT "HELP" provided clear explanations when the material was difficult to understand./ The instructor provided clear explanations when the material was difficult to understand.	10	4.02	1.00	6	4.32	.84
The rule statements ("RULE") on TICCIT made concepts in writing easy to learn./ The class lectures made concepts in writing easy to learn.	11	4.19	.81	4	3.88	1.00
Doing practice questions ("PRACTICE") helped me in learning rules and concepts in writing./ Homework assignments helped me in learning rules and concepts in writing.	9	4.46	.71	10	3.83	.91
TICCIT's comments on my work ("ADVICE") helped me to progress through this course./ The instructor's comments on my work helped me to progress through this course.	8	3.72	1.13	12	3.97	1.07
Other stems:						
Taking tests in this course let me know whether or not I really understood the material.	12	4.38	.82	7	4.17	.91
Examples ("EXAMPLE") really did not show me how to write well.	13	2.71	1.17	8	2.65	1.20

Table 6.5(a)

	TICCIT (N ≅ 110)			Lecture (N ≅ 177)		
Item Stems	Item Number (Form 068)	Mean	sd	Item Number (Form 067)	Mean	sd
In this course I felt responsible for my own learning.	14	4.44	.61	9	3.98	1.04
Other students in this section seemed to like the course.	18	3.61	.81	15	3.59	.95
I was satisfied with my personal progress in this course.	20	4.22	.90	18	3.68	1.12
Time passed quickly while I was in class.	25	4.40	.83	22	3.70	1.26
Information statements:						
I wanted information that would tell me where I stood in comparison to other students.	29	2.55	1.38	24	2.64	1.38
For me, the pace at which I had to cover the material in order to finish the course was:	30	2.90	.65	25	2.94	.79
For my preparation and ability, most of the work in this course was:	31	2.79	.76	26	3.00	.74
The work load for this course, in relation to other courses of equal credit, was:	32	3.65	.90	27	3.19	.88

Item Coding (Form 068):

(Items 1-24)	(Items 25-29)	(Item 30)	(Item 31)	(Item 32)
5 = Strongly Agree	5 = Almost Always	5 = Very Slow	5 = Very Difficult	5 = Much Lighter
4 = Agree	4 = Frequently	4 = Somewhat Slow	4 = Somewhat Difficult	4 = Lighter
3 = Not Sure	3 = Not Sure	3 = About Right	3 = About Right	3 = About the Same
2 = Disagree	2 = Occasionally	2 = Somewhat Fast	2 = Somewhat Easy	2 = Heavier
1 = Strongly Disagree	1 = Almost Never	1 = Very Fast	1 = Very Easy	1 = Much Heavier

Table 6.5(b)

stems. But these data show mean responses from TICCIT classes higher than those from lecture-discussion sections. Almost all statements had responses indicative of a more positive attitude among students who had completed the courses on the TICCIT system rather than in a lecture-discussion section.

What mean responses to individual statements tell us about student attitudes may be unclear. Yet such responses can provide useful information in understanding the estimates of treatment effects on student attitudes and in reaching conclusions about the strengths and weaknesses of the TICCIT program. It might, therefore, be worthwhile to consider at least a few examples. The first item listed in Table 6.4, item 20 on Form 035 "I would recommend this course to my friends," had mean responses of 3.27 in TICCIT classes and 3.91 in lecture sections. The response scale for that statement went from strong agreement to strong disagreement, scored as five points down to one point. While students in lecture sections agreed that they would recommend their mathematics course to friends, students completing the same course under the TICCIT program were unsure about making such a recommendation. Distributions of item responses make this point even clearer: one-fourth of the students in TICCIT classes would not recommend the course while less than one-tenth of the students in lecture sections would do the same. Surely this has implications for student satisfaction with the instructional condition.

Other response means from Table 6.4 indicate that lecture sections better met each student's particular needs (item 6 on Form 035), that students received more individual attention from instructors in lecture sections (item 3 on Form 035), that instructors in lecture sections provided much better explanations of difficult material than did the HELP feature on the TICCIT system (item 10 on Form 035). Admittedly these responses reflect student opinions, and their perceptions may be inaccurate. They do, however, reveal how students felt about their courses and remain pertinent in evaluating impact on attitudes. From the students' standpoint only the practice problems on the TICCIT system met the standards of lecture sections. Computer-assisted instruction in itself did not guarantee instruction tailored to the individual student.

Most of these observations can be repeated for the English courses included in Table 6.5 with the opposite emphasis. Students in these TICCIT classes did feel that the instruction had better met their own particular needs (item 6 on Form 068), that they had received greater individual attention from instructors (item 3 on Form 068), that practice problems on the TICCIT system helped them in learning rules and concepts in writing (item 9 on Form 068). And most students who had taken these English courses on the TICCIT system would strongly recommend the same course to their friends: the majority of students from TICCIT classes either strongly agreed (42%) or agreed (40%) with this question on the survey (item 23 on Form 066). Unlike other aspects of student performance, it appears that the TICCIT program affected student attitudes sometimes in a positive manner and sometimes in a negative manner when compared against the reactions of students in traditional sections of the same courses.

6.2.b Specific Statements

The student surveys contained some statements that were specific to an instructional condition. These statements covered aspects of TICCIT classes or lecture sections without definite parallels in another condition. Despite this lack of parallel and a consequent restriction on any comparisons across conditions, we believed that student reactions to these unique course attributes should be obtained. The role of these specific statements might be likened to the role of the items on the achievement posttests that reflected objectives unique to one condition or another: they help us in documenting outcomes of importance independent of their frequency of occurrence. By the same token there may be specific statements of another kind. A set of item stems permits student responses on a limited number of course components. Students' own comments may go beyond these components in pointing out other instructional strengths or weaknesses in a course. These comments constitute an additional source of specific statements reflecting student attitudes.

Item Responses. Table 6.6 presents response means and standard deviations for survey statements unique to a particular instructional condition. The courses included in the table are the same as those covered in the item summaries for common statements (see Tables 6.4 and 6.5). Appendix R has similar tables for all courses.

From the statements specific to TICCIT classes it is apparent that students could use the system's map structures to guide their learning of the subject matter (item 7 on Form 035), and could readily master the mechanical procedures necessary for operating the terminals (item 23 on Form 035). The TICCIT program did enable each student to set a pace appropriate to his or her ability, and it made students active participants in the process of learning. There was a clear consensus of agreement with statements relevant to these two features of the program (items 2 and 5 on Form 035). Despite the short duration of system failures (see Chapter 7: Student Activities), interruptions of computer service disrupted student learning (item 15 on Form 035). The lower incidence of agreement with this statement in English courses offered on the TICCIT system a full year later than the mathematics courses seems to indicate that disruptions caused by computer breakdowns

Student Attitude Survey:
Item Responses Specific to Instructional Conditions
Phoenix College
Mathematics Courses, Fall Semester 1975 and English Courses, Fall Semester 1976

Item Stems for TICCIT Classes	Item Number (Form 035)	Mathematics Courses (N ≅ 64) Mean	sd	Item Number (Form 068)	English Courses (N ≅ 110) Mean	sd
Using TICCIT allowed me to set a pace that was right for my ability.	2	4.06	1.26	2	4.48	.82
Through TICCIT I became actively involved in my own learning.	5	3.95	1.17	5	4.33	.72
I didn't understand how to use "MAP" to guide my learning in this course.	7	1.91	1.06	7	1.73	1.04
Breakdowns of the computer system disrupted my learning.	15	4.03	1.15	15	3.51	1.44
I would take another course that uses TICCIT.	21	3.42	1.58	24	3.89	1.18
The mechanics of using the terminal distracted me from learning.	23	1.78	.91	26	1.80	1.02
I wanted a regular textbook for this course to use as a reference at home.	25	2.78	1.60	26	2.28	1.34

Item Stems for Lecture Classes	Item Number (Form 040)	Lecture (N ≅ 260) Mean	sd	Item Number (Form 067)	Lecture (N ≅ 177) Mean	sd
I found the textbook useful in explaining the material and presenting methods for (solving problems/writing well).	5	3.22	1.23	5	4.01	1.05
Class discussions and student questions assisted me in learning the material.	11	4.07	.95	11	3.97	.87

Table 6.6

diminished with time. Student opinions about taking another course on the TICCIT system (item 21 on Form 035) and about needing a regular textbook as a convenient reference (item 25 on Form 035) varied considerably. The response means to these two statements suggest that students generally would enroll in another course under the TICCIT program and felt no need for a regular textbook. However, a sizeable percentage of students in mathematics courses would avoid subsequent TICCIT classes (29%) and a large proportion (39%) wanted a textbook to be made available for use away from the computer system.

Student responses to statements applicable only to lecture sections offer additional insight for interpreting the attitude results. Although students in English courses found their textbooks useful in explaining and presenting material (item 5 on Form 067), mathematics textbooks were viewed as less helpful. Indeed, one-half of the students in lecture sections of math courses did not find their textbooks to be effective in explanations and presentations of problem solving. If the TICCIT program replaced just textbooks, the appropriate standard for comparisons of attitude results would be much lower in mathematics courses. But the program had been intended to supplant regular classroom instruction and raise student-teacher ratios. Given students' favorable reactions to class discussions and to student questions as devices for learning (item 11 on Form 035), there was an important element of classroom interactions absent from TICCIT classes. The English courses on the TICCIT system that incorporated supplemental small group discussions were the TICCIT classes which showed positive attitude results in comparisons with lecture-discussion sections (see Table 6.5).

Student Comments. The attitude surveys provided students with an opportunity to comment freely and to elaborate on their reactions to a course. There were several recurrent points in these comments, mostly remarks about specific features of the TICCIT program. Although students often offered additional praise of the program, these positive comments tended to be redundant with their responses to particular statements already on the survey. It is the constructive criticism that seems most pertinent to further refinements of the TICCIT program and to understanding student attitudes in mathematics courses.

Students frequently raised six points in commenting about a course under the TICCIT program. The high student-teacher ratio in some mathematics courses led to complaints about ready access to instructors. There was such demand for instructor assistance in explaining concepts and supervising mastery tests that individual students had to wait for answers to their questions about content. Two other points often mentioned by students begin to account for their need of instructor assistance. When students requested additional help on the TICCIT system, the explanations given to them still seemed to skip steps involved in applying a rule or in solving a problem. The level of detail given in the HELP sequences was not sufficient for all students. Also, students with a specific question about a rule or problem turned to instructors for an answer. The TICCIT program could provide answers to just those student questions that the courseware developers had anticipated and incorporated into the curriculum; the computer system could not respond to a direct inquiry.

Students also commented on the structure of the TICCIT curriculum which required that students master one unit before proceeding to another unit higher on the courseware map. Sometimes this impeded rather than facilitated student progress. Students cited the fact that lecture sections permitted them to continue with their studies and to return later to an omitted topic when they had a better grasp of the subject matter. A student stuck on a unit in the TICCIT curriculum had to stay with that unit. Perhaps the inordinate amount of time spent on particular units prompted other remarks about the need to devote an excessive amount of time to TICCIT classes or to cover too much material. Although responses to particular item stems had indicated that the work load and pace of courses under the TICCIT program generally matched student ability, some students objected to the study demands of TICCIT classes. Finally, students believed that the TICCIT system mistakenly judged their correct answers to be incorrect. It caused noticeable frustration when the computer system failed to recognize correct answers unless the answers conformed to its notational conventions, or when system feedback on student solutions to practice problems failed to acknowledge a correct answer.

Some of these comments suggest specific steps for improving the TICCIT program. Refinements to the procedures for judging answers could enable the computer system to accommodate equivalent forms of correct answers for practice problems. The hierarchical structure could be made flexible enough for students to leave a particularly troublesome unit, especially if it were not essential to other topics, or the curriculum might attempt alternative explanations of difficult concepts. Course requirements might be adapted to reflect realistic expectations of what students could accomplish within an academic term, or colleges might award partial credits in recognition of the progress that each student had made within a term. And the student-teacher ratio should not exceed the usual ratio of regular classes unless experience warrants a higher load.

Yet it would seem impractical to attempt resolving all student criticism. The resources necessary for developing a computer system capable of responding to any student question about the subject matter would, at the present stage of instructional technology, be prohibitive. Similarly, it may be impossible to construct remedial instructional sequences of sufficient detail to satisfy every student in as heterogeneous a population as found at community colleges. The instructor has an essential role in applications of computer-assisted instruction.

These comments about the TICCIT program had been chosen for their potential usefulness in subsequent implementations. There were also frequent positive remarks about both TICCIT classes and lecture sections. It would be inappropriate to infer that students were always or mostly critical of the TICCIT system. Each instructional condition had definite strengths. As a student in a mathematics course under the TICCIT program wrote:

> The amount of knowledge I have acquired and the speed at which I had done so would almost certainly have been impossible through more conventional instruction, i.e., lecture-textbook.

Another student's comment about a lecture section of a mathematics course was:

> The instructor is marvelous. She knows her material and is interested in it and made a great effort to get us interested in it and math in general. Her approach really and honestly got me interested in the subject and it changed my view of math. Now, I like math.

Perhaps the English classes on the TICCIT system that incorporated occasional small group discussions combined the strengths of both approaches and therefore had a positive impact on student attitudes.

6.3 Analysis of Program Effects

The differences in student attitude scores evident from the descriptive data may reflect real treatment effects or other factors. If students of higher entrance ability tended to react less favorably to their courses, the higher pretest scores of students completing mathematics courses under the

TICCIT program may account for some of the differences. Perhaps the instructors responsible for English courses on the TICCIT system, especially courses with regular classroom sessions as well as computer classes, were particularly energetic and enthusiastic or particularly unimaginative and dull, and these differences among teachers might explain apparent treatment effects. Or the differences in attitude scores may have been too small to justify drawing conclusions about the affective impact of the TICCIT program.

Our approach to data analysis allows us to isolate treatment effects and consider other plausible explanations for observed differences in student attitudes. Again the number of students in the population of interest, students who completed courses under the TICCIT program, will restrict the set of independent variables that can enter into the analyses for math courses. There were too few observations from this population to use a full set of demographic characteristics in defining student similarity. As in the analyses for student achievement, we will rely on entrance ability in mathematics to identify students from lecture sections comparable to those students who completed math courses on the TICCIT system. In English courses there were higher completion rates and larger sample sizes. The analyses for English courses can, therefore, take into account numerous possible sources of differences in student attitudes besides student attitudes.

The estimates of treatment effects presented here reflect the influence of the TICCIT program on student attitudes. Each estimate represents the difference between the actual attitude score of a student who completed a course under the TICCIT program and the probable score of that student had he or she been in a lecture section of the same course. We estimate treatment effects on the total attitude score for all common statements as well as on subscores for the scales established through factor analyses of item responses.

6.3.a Math Courses

Tables 6.7 and 6.8 present the analyses of attitude results for math courses. Of the 12 analyses for courses within terms, the direction of the estimated treatment effects was negative in 11 cases. Students reacted less favorably to a mathematics course under the TICCIT program than to the same course in a lecture format. Yet there were only three instances in which the impact on students' overall attitudes toward a course reached a statistically significant level. Furthermore, there was just one case of a significant effect on the attitude subscore representing students' personal satisfaction with their course. But the difference in students' reactions to specific features of the TICCIT system and their reactions to the counterparts of those features in sections was significant in ten analyses: students consistently rated the basic options of TICCIT's learner control as less helpful in their learning than the parallels of these options in lecture sections.

The three cases of a statistically significant negative effect on overall attitudes occurred in math courses which had higher student-teacher ratios in TICCIT classes than in lecture sections. Moreover, every estimated treatment effect was negative in such courses. Table 6.7 shows these results. In this table, as well as in those which follow, the regression weight (b) for the independent variable representing instructional condition corresponds to the estimated treatment effect ($\hat{\tau}$) and the value of the t-statistic (t) associated with this variable indicates the statistical significance of the effect. Significant differences in overall attitudes (i.e., students' scores on those statements that appeared in identical or closely parallel form across conditions) can be seen in Math 007 for the fall and spring semesters and in Math 108 for the spring semester of the

386

Attitude Results Analysis on Common Statements
Mathematics Courses, Phoenix
Academic Year 1975-76

				Dependent Variable							
				Overall Attitudes		Course Satisfaction		Individual Attention		System Features	
Course	Term	Number of Students	Independent Variable	b	t	b	t	b	t	b	t
Math 007	Fall	135	Condition TICCIT(1)/Lecture(0)	-6.15	-2.44*	-2.22	-2.03*	-2.16	-2.64**	-1.48	-3.25**
			Division Day(1)/Evening(0)	-1.61	- .76	-1.18	-1.28	- .14	- .20	- .10	- .26
			Entrance Ability Pretest	.18	2.09*	.08	2.18*	.02	.81	.01	.90
			Constant	63.36		19.89		14.24		11.94	
				R = .31		R = .31		R = .25		R = .30	
	Spring	131	Condition TICCIT(1)/Lecture(0)	-6.70	-2.07*	-1.62	-1.17	-2.45	-3.00**	-1.90	-2.33*
			Division Day(1)/Evening(0)	1.72	.80	.42	.45	.57	1.04	1.20	2.21*
			Entrance Ability Pretest	.15	1.59	.09	2.16*	.03	1.11	.05	1.99*
			Constant	67.78		19.14		14.24		13.70	
				R = .22		R = .21		R = .27		R = .28	
Math 106	Fall	46	Condition TICCIT(1)/Lecture(0)	-6.69	-1.93	-2.69	-1.60	-1.57	-1.86	-2.23	-3.16**
			Entrance Ability Pretest	.34	1.90	.16	1.82	.07	1.56	.05	1.30
			Constant	52.38		14.24		11.56		10.63	
				R = .38		R = .35		R = .35		R = .46	
	Spring	79	Condition TICCIT(1)/Lecture(0)	-3.97	-1.03	- .24	- .14	-2.14	-1.98	-2.29	-2.16*
			Entrance Ability Pretest	.08	.21	.05	.32	- .04	- .36	.06	.64
			Constant	73.55		22.09		15.77		16.07	
				R = .12		R = .04		R = .24		R = .24	
Math 108	Fall	42	Condition TICCIT(1)/Lecture(0)	-7.39	-1.91	-2.34	-1.29	-3.59	-3.42**	-1.73	-2.70*
			Entrance Ability Pretest	- .15	-1.00	- .05	- .69	- .03	- .62	- .03	-1.06
			Constant	81.26		26.44		17.69		14.90	
				R = .36		R = .25		R = .51		R = .46	
	Spring	50	Condition TICCIT(1)/Lecture(0)	-7.82	-2.56*	-2.48	-1.70	-2.85	-3.35**	-2.66	-3.53**
			Entrance Ability Pretest	.10	.71	.06	.80	.05	1.15	.03	.72
			Constant	72.37		21.14		14.41		16.19	
				R = .35		R = .26		R = .45		R = .46	
Math 117	Spring	53	Condition TICCIT(1)/Lecture(0)	-7.42	-1.80	-2.08	-1.19	-2.42	-2.01	-2.43	-2.29*
			Division Day(1)/Evening(0)	9.95	2.90**	2.96	2.03*	2.29	2.29*	2.24	2.53*
			Entrance Ability Pretest	- .43	- .99	- .10	- .56	- .13	-1.01	- .09	- .79
			Constant	71.70		21.73		14.93		16.30	
				R = .41		R = .30		R = .38		R = .41	

$^{*}p<.05$
$^{**}p<.01$

Table 6.7

Attitude Results: Analysis on Common Statements
Mathematics Courses, Alexandria
Academic Year 1975-76

				Dependent Variable							
				Overall Attitudes		Course Satisfaction		Individual Attention		System Features	
Course	Term	Number of Students	Independent Variable	b	t	b	t	b	t	b	t
Math 31	Fall	38[1]	Condition TICCIT(1)/Lecture(0)	-5.59	-1.17	-1.99	- .89	- .45	- .43	-2.36	-2.76**
			Entrance Ability Pretest	.15	.85	.06	.68	.00	.00	.06	1.89
			Constant	68.44		21.11		17.44		10.58	
				R = .21		R = .16		R = .08		R = .44	
	Winter	61	Condition TICCIT(1)/Lecture(0)	1.21	.40	.15	.11	1.10	1.33	- .60	- .68
			Division Day(1)/Evening(0)	-5.57	-2.12*	-2.44	-2.05*	- .91	-1.28	-1.32	-1.74
			Entrance Ability Pretest	- .19	-1.52	- .07	-1.26	- .03	- .77	- .05	-1.51
			Constant	82.36		25.74		16.86		18.16	
				R = .32		R = .29		R = .25		R = .28	
	Spring	29	Condition TICCIT(1)/Lecture(0)	-5.78	-1.02	-2.57	-1.06	-3.08	-2.87**	- .01	- .01
			Division Day(1)/Evening(0)	3.02	.58	1.83	.82	1.45	1.46	-1.00	- .78
			Entrance Ability Pretest	- .03	- .15	.01	.14	- .05	-1.43	.06	1.35
			Constant	76.69		22.89		19.64		13.08	
				R = .20		R = .23		R = .53		R = .35	
Math 32	Winter	32	Condition TICCIT(1)/Lecture(0)	-7.94	-2.02	-2.62	-1.73	-1.23	-1.19	-3.71	-3.52**
			Division Day(1)/Evening(0)	-14.38	-3.84***	-5.24	-3.63**	-3.22	-3.29**	-2.41	-2.40*
			Entrance Ability Pretest	- .15	- .29	- .18	- .86	- .01	- .05	.02	.16
			Constant	85.53		28.37		18.29		17.52	
				R = .66		R = .64		R = .57		R = .65	
	Spring	45	Condition TICCIT(1)/Lecture(0)	-4.33	-1.47	-1.56	-1.19	.12	.15	-3.22	-3.96***
			Division Day(1)/Evening(0)	-5.73	-2.06*	-2.68	-2.17*	- .88	-1.18	.20	.26
			Entrance Ability Pretest	- .35	- .70	- .25	-1.16	- .04	- .30	- .04	- .26
			Constant	84.58		28.44		17.96		16.82	
				R = .43		R = .44		R = .18		R = .56	

*$p<.05$

**$p<.01$

***$p<.001$

[1] Includes only those students who received course credit.

Table 6.8

1975-76 academic year. The size of these effects and most others listed in Table 6.7 is roughly one-half of a standard deviation. This would be large enough to change the mean responses on six or seven statements from a consensus of agreement with a positive item stem to an uncertain position. Clearly the TICCIT program had a negative impact on student attitudes toward mathematics courses.

Looking at the estimated treatment effects for attitude subscores we can identify the source of this negative effect. Since there was only one significant effect on the scale of Course Satisfaction, it would seem that students viewed the course itself and the fit of instruction in the course to their own needs as favorably in TICCIT classes as in lecture sections. Math courses under the TICCIT program generally met the standards of traditional lecture practices if we use students' personal satisfaction with a course as a criterion. However, the scales for Individual Attention and System Features reveal less desirable outcomes.

Two of the courses included in Table 6.7, specifically Math 007 and Math 108, show a statistically significant treatment effect on the attitude subscore for individual Attention. The effect was evident in both the fall and spring academic terms. Furthermore, the same attitude subscale had a negative estimate for treatment effect in each course where the student-teacher ratio in TICCIT classes exceeded that in lecture sections (i.e., every course in Table 6.7). The conclusion seems clear: Increases in the student-teacher ratio for math courses under the TICCIT program will detrimentally affect student perceptions of the amount of individual attention devoted to them. This happened especially in those courses which constituted the first math course taken by community college students, and it happened despite the availability of proctors for assisting students.

The analyses for attitude results also led to statistically significant estimates of treatment effects for every mathematics course on the attitude scale of System Features. Each estimated effect on this scale was negative and significant at Phoenix; the effect held across courses and terms. At Alexandria there was a significant, negative effect in both Algebra I and Algebra II (Math 31 and Math 32), and the effect was replicated in Algebra II. Of the 12 analyses performed for examining attitude results in math courses there were ten cases of a significant, negative effect on the attitude scale of System Features. The functions called RULE and HELP on the TICCIT system, intended to present mathematical rules and concepts and to provide assistance in understanding rules and solving problems, received less favorable student ratings than did class lectures and instructor explanations. Yet RULE statements served much the same purpose as lectures in that they both present material in an expository manner, and HELP sequences were essentially replacements for the elaboration an instructor might give on difficult material. With the notable exception of practice problems, which seemed to fulfill the role of homework assignments (see responses to item 9 in Appendix R), students believed traditional practices to be of greater assistance in their learning than particular features built into the TICCIT system.

The pattern of attitude results in mathematics courses is as clear and consistent as it had been for course completion rates and student achievement. But the estimated treatment effects on course completion rates had been negative and significant, and those for student achievement positive and significant. Estimates of treatment effects on overall student attitudes were negative and generally not statistically significant. Instead there were statistically significant differences on particular attitude scales.

In courses with a higher student-teacher ratio in the TICCIT condition than in lecture sections, students reported receiving less individual attention when a mathematics course fell under the TICCIT program. Throughout math courses students rated specific features of the TICCIT system less favorably than the aspects of lecture classes corresponding to those features.

6.3.b English Courses

Tables 6.9 and 6.10 present analyses of attitude results in English courses. These analyses reflect the same approach to estimating treatment effects as had been applied for mathematics courses. However, the population of students completing a math course under the TICCIT program was generally limited in number. The larger sample of such students in English courses permitted the use of a fuller set of independent variables. Furthermore, students in English courses responded to the same form of the attitude survey across academic terms. This enabled us to collapse attitude data across terms and conduct one analysis with an even larger number of students in the relevant population. In English courses we rely on an expanded set of variables for identifying similar students and a larger number of observations for determining possible treatment effects.

The analyses for English courses conducted with small group discussion as a supplement to instruction given on the TICCIT system appear in Table 6.9. Since interaction terms entered into the regression model, the regression weight (b) for the variable representing instructional condition does not correspond to an estimated treatment effect. Instead the sum of that coefficient and the product of the interaction term yield an estimate of the impact of the TICCIT program on student attitudes. Since the mean age of students in TICCIT classes was just over 23 years, we can calculate the average treatment effect on overall attitudes (OA) as $\hat{\tau}_{OA} = (15.2457) +$

Attitude Results: Analysis on Common Statements
English Courses, Phoenix
Calendar Year 1976

Dependent Variable:	Overall Attitudes		Course Satisfaction		Individual Attention		System Features	
Number of Students:	316		316		316		316	
Multiple Correlation:	.34		.32		.36		.29	
	b	t	b	t	b	t	b	t
Condition								
TICCIT(1)/Lecture(0)	15.25	3.08**	7.92	3.52***	.98	3.41***	.88	1.72
Entrance Ability								
Essay Pretest	1.00	.96	.43	.91	.19	.99	.15	.59
Objective Pretest	- .22	-1.91	- .11	-2.15*	- .01	- .21	- .06	-2.34*
Division								
Day(1)/Evening(0)	-1.94	- .91	- .30	- .31	- .44	-1.10	- .50	-1.00
Term								
Spring(1)/Fall(0)	3.59	2.27*	1.05	1.46	.95	3.23**	.84	2.28
Instructor								
I1	4.34	1.71	1.42	1.23	.96	2.01*	.89	1.49
I3	-3.72	-1.05	-1.44	- .90	.09	- .14	.23	.28
Student Status								
Full-time(1)/Part-time(0)	-1.47	- .80	-1.40	-1.68	.42	1.24	- .01	- .02
Enrollment in Course:								
Repetition of course(1)/ First enrollment(0)	3.77	.82	1.28	.62	.94	1.09	.38	.35
Employment								
Full-time(3)/Part-time(2)/ None(1)	-1.99	-1.95	- .92	-1.99*	- .35	-1.84	- .35	-1.47
Maturity								
Age(years)	.27	2.42*	.14	2.74**	.04	2.26*	.03	1.40
Sex								
Male(1)/Female(0)	-2.31	-1.67	- .81	-1.28	.09	.34	- .28	- .72
Other								
TICCIT* Age	- .47	-2.28*	- .27	-2.95**				
TICCIT* Sex							-1.42	-2.04*
Constant	84.87		32.45		11.24		17.47	

*p<.05

**p<.01

***p<.001

Table 6.9

Attitude Results: Analysis on Common Statements
English Courses, Alexandria
Calendar Year 1976

Dependent Variable:	Overall Attitudes		Course Satisfaction		Individual Attention		System Features	
Number of Students:	440		440		440		440	
Multiple Correlation:	.48		.48		.50		.41	
	b	t	b	t	b	t	b	t
Condition								
TICCIT(1)/Lecture(0)	-6.51	-4.50***	-3.34	-5.08***	-1.37	-4.76***	-1.28	-3.54***
Entrance Ability								
Essay Pretest	10.36	2.38*	5.79	2.94**	- .09	- .56	- .23	-1.05
Objective Pretest	.09	.99	.05	1.28	.01	.34	.01	.63
Division								
Day(1)/Evening(0)	5.23	2.98**	2.03	2.55*	.69	2.06*	1.37	3.15**
Class								
Laboratory(1)/Regular(0)	.34	.21	.22	.29	- .05	- .14	- .54	-1.31
Term								
Winter(1)/Fall(-1)/Spring(0)	-9.13	-3.15**	-4.73	-3.60***	- .11	- .49	- .30	-1.05
Spring(1)/Fall(-1)/Winter(0)	1.69	1.92	.83	2.11*	.05	.29	.18	.82
Instructor								
I1	- .83	- .38	.12	.13	-1.28	-3.13**	.11	.20
I2	-8.89	-3.37***	-3.25	-2.72**	-1.48	-2.98**	-2.09	-3.20**
I3	-1.94	- .66	- .39	- .29	1.07	1.44	- .42	- .58
I4	1.90	.67	.79	.61	.85	1.57	.06	.08
I5	-11.47	-5.17***	-4.60	-4.58***	-1.62	-3.88***	-1.94	-3.55***
I6	-3.29	-1.37	- .96	- .88	-1.15	-2.54*	- .17	- .29
Student Status								
Full-time(1)/Part-time(0)	2.86	1.86	1.34	1.92	.64	2.21*	.45	1.19
Enrollment in Course								
Repetition of course(1)/ First enrollment(0)	- .83	- .36	- .07	- .06	- .04	- .08	- .52	- .90
Employment								
Full-time(3)/Part-time(2)/ None(1)	1.86	2.21*	.73	1.92	.29	1.79	.58	2.79**
Maturity								
Age(years)	.23	2.82**	.10	2.70**	.06	3.50***	.05	2.20*
Sex								
Male(1)/Female(0)	-3.37	-2.90**	-1.27	-2.40*	- .36	-1.65	- .96	-3.34***
Other								
Essay Pretest* Essay Pretest	-2.17	-2.58*	-1.23	-3.21**				
Winter* Essay Pretest	3.26	3.10**	1.69	3.53***				
TICCIT* I5					-3.06	-3.27**		
Constant	56.85		18.28		10.34		14.39	

$^{*}p<.05$
$^{**}p<.01$
$^{***}p<.001$

Table 6.10

$(-.4662)\ 23.05 \simeq 4.50$, where the values within parentheses come from the regression coefficients for the categorical variable of instructional condition and for the interaction term. The t-statistic associated with this estimated treatment effect is 2.34 ($p<.05$). Similarly, the estimated treatment effect on the attitude scale of Course Satisfaction (CS) is $\hat{\tau}_{CS} = (7.9179) + (-.2735)\ 23.05 \simeq 1.61$ with a t-statistic of 2.31 ($p<.05$). Although there is another interaction term indicating that male students viewed specific features of the TICCIT system more favorably than female students did, the estimates of treatment effects on this attitude scale fell below a statistically significant level for both sexes.

There were statistically significant differences in the attitudes of students completing English courses on the TICCIT system and those of comparable students from lecture-discussion classes. Students, particularly younger students, reacted more favorably to classes on the TICCIT system than to conventional sections of the same English course; they expressed a greater degree of personal satisfaction with the course and believed a greater amount of individual attention had been given to them. The estimates of treatment effects on the attitude score for overall attitudes and the subscore for course satisfaction, 4.50 and 1.61 respectively, hold for students of the average age in TICCIT classes. These effects would be even larger for a community college student who was 18 years of age: $\hat{\tau}_{AO} = 6.85$ and $\hat{\tau}_{CS} = 2.99$. Since the estimated treatment effect varied inversely with student age, the size of the effect diminishes for older students and becomes negative beyond an age of 30 years. Few students actually fell in this age group. As implemented in English courses at Phoenix College the TICCIT program had a positive impact on students' attitudes toward their course.

When students spent time on the TICCIT system as well as attended regular classroom sessions, the affective outcomes were quite different. Members of the English faculty at Alexandria decided to use the TICCIT curriculum and still hold classroom meetings. Although students spent considerable amounts of time on the TICCIT system (see Chapter 7: Student Activities), these TICCIT classes no longer adhered to the principle of mainline instruction. Students learned both from the TICCIT program and from teachers, without a clear definition of the relationship between these two resources. Individual instructors chose which courseware units their students would study: some instructors tried to use the TICCIT system as much as possible, and others gave minimal assignments in the TICCIT courseware. As shown in Table 6.10, students reacted less favorably to an English course when it included study on the TICCIT system.

Other factors besides use of the TICCIT system affected student attitudes in English courses at Alexandria. Some of these factors involved student characteristics while others reflected the context of the course. Older students tended to react more favorably to their course regardless of its instructional condition. Male students expressed less positive opinions about their course than did female students. There was a curvilinear relationship between student attitudes and their scores on the essay pretest: students with extremely low or high scores on the essay pretest had lower attitude scores, on all common statements (Overall Attitudes) and on the scale for Course Satisfaction, than students with middle scores on the essay pretest. Perhaps both the students least competent in writing and those already facile in writing derived less benefit from their course in composition than they had expected.

Variables representing the context within which a particular section was held also contributed to the explanation of variance in student attitudes. Students in classes offered during daytime school hours generally had higher attitude scores than did students in sections given in the evening. Reactions to Alexandria's English 111 were most positive in the spring quarter and least positive in the winter quarter, with reactions from the fall quarter closer to those of the winter term. Particular instructors, notably I2 and I5 in Table 6.10, also affected student attitudes toward their course. Students with instructor I5 for a section on the TICCIT system reported receiving less individual attention than did students with the same instructor for a lecture-discussion section (see the regression coefficient in Table 6.10 for the interaction term, TICCIT*I5, on the attitude scale for Individual Attention).

The significance of these student characteristics and context variables in the regression model does not change the direction or size of the estimated treatment effects reported in Table 6.10. Coefficients for the dichotomous variable of instructional condition still represent our best estimate of treatment effects. Other variables in the regression model simply contributed to the explanation of variance in attitude scores and to the identification of similar students across conditions. Besides the one instructor-treatment term applicable to a single section with 12 students, there was no interaction which would affect estimates of treatment effects.

While student attitudes toward a course rose in TICCIT classes sometimes supplemented by small group discussions, a mixture of sessions on the TICCIT system and regular classroom meetings led to less favorable student reactions. In both cases the standard for comparisons had been student attitudes in lecture-discussion sections of the same English courses. That analyses revealed statistically significant positive and negative treatment effects seems neither inconsistent nor contradictory. The results of the TICCIT program, like those of any other instructional resource or educational tool, depended on the manner of its use.

6.3.c Estimated Treatment Effects

A summary of the treatment effects estimated for student attitudes appears in Table 6.11. Each estimate reflects difference in the attitude scores of students completing a course under the TICCIT program as contrasted with the scores of similar students in lecture-discussion sections of the same course. A positive treatment effect indicates that students in TICCIT classes had higher attitude scores than did comparable students in lecture-discussion sections, and a negative treatment effect indicates that students reacted less favorably to a course offered on the TICCIT system than to the same course conducted in a traditional manner. The scores themselves stemmed from student responses to statements about the course, statements phrased in an identical or closely parallel form across instructional conditions (see Tables 6.4 and 6.5). There was one total attitude score, called Overall Attitudes, representing the extent of student agreement with all such statements as well as three subscores representing students' reactions to specific aspects of a course (see Table 6.1). Estimates of treatment effects on these scales reveal the extent of TICCIT's impact on student attitudes and identify the source of that impact.

Math Courses. Of the twelve analyses for mathematics courses within terms, there were three significant treatment effects on students' overall attitudes. Each of these effects was negative: students in TICCIT classes reacted less favorably to their math course than did students of comparable ability in lecture sections. That eight other estimates of treatment effects were also negative confirms the negative impact of the TICCIT program on student attitudes in math courses. Yet there was only one case in which students expressed significantly less personal satisfaction with a course under the TICCIT program. It occurred in the first academic term of the demonstration and probably represents an overestimate of treatment effects given the differences found in other courses and subsequent terms. Students' perceptions of a course in relation to their own needs and personal progress do not seem to account fully for the size and direction of the treatment effects on overall attitudes.

The reasons behind the less favorable reactions to math courses under the TICCIT program become evident from the estimates of treatment effects on the attitude scales for Individual Attention and System Features. When there was a higher student-teacher ratio in TICCIT classes than in regular classes, students in those TICCIT classes reported receiving less individual attention. Under such conditions the estimated treatment effects on the attitude scale for Individual Attention were statistically significant and negative in four cases out of seven. The other three cases also showed negative effects on Individual Attention, and these closely approached statistically significant levels. Moreover, the significant effects occurred across academic terms for mathematics courses in beginning algebra (Math 007 and Math 108 in Table 6.11).

On the attitude scale for System Features the estimated treatment effects were statistically significant and negative in ten cases out of twelve analyses for math courses within terms. The HELP sequences available on the TICCIT system did not match instructors' explanations of difficult material in regular classes. Nor did the presentation of mathematical rules and concepts (RULE) under the TICCIT program facilitate student learning to

Estimated Treatment Effects on Student Attitudes

College	Term	Course	Number of Students	Overall Attitudes Effect($\hat{\tau}$)	Overall Attitudes t-Statistic	Course Satisfaction Effect($\hat{\tau}$)	Course Satisfaction t-Statistic	Individual Attention Effect ($\hat{\tau}$)	Individual Attention t-Statistic	System Features Effect($\hat{\tau}$)	System Features t-Statistic
Phoenix	Fall 1975	Math 007	135	-6.15	-2.44*	-2.22	-2.03*	-2.16	-2.64**	-1.48	-3.25**
		Math 106	46	-6.69	-1.93	-2.69	-1.60	-1.57	-1.86	-2.23	-3.16**
		Math 108	42	-7.39	-1.91	-2.34	-1.39	-3.59	-3.42**	-1.73	-2.70*
	Spring 1976	Math 007	131	-6.70	-2.07*	-1.62	-1.17	-2.45	-3.00**	-1.90	-2.33**
		Math 106	79	-3.97	-1.03	- .24	- .14	-2.14	-1.98	-2.29	-2.16*
		Math 108	50	-7.82	-2.56*	-2.48	-1.70	-2.85	-3.35*	-2.66	-3.53**
		Math 117	53	-7.42	-1.80	-2.08	-1.19	-2.42	-2.01	-2.43	-2.29*
	Spring & Fall 1976	English 19 & 29	316	4.50[1]		1.61[1]	2.31*	.98	3.41***	.88[2]	1.72
										-.54[3]	-1.10
Alexandria	Fall 1975	Math 31	38	-5.59	-1.17	-1.99	- .89	- .45	- .43	-2.36	-2.76**
	Winter 1976	Math 31	61	1.21	.40	.15	.11	1.10	1.33	- .60	- .68
		Math 32	32	-7.94	-2.02	-2.62	-1.73	-1.23	-1.19	-3.71	-3.52**
	Spring 1976	Math 31	29	-5.98	-1.02	-2.57	-1.06	-3.08	-2.87**	- .01	- .01
		Math 32	45	-4.33	-1.47	-1.56	-1.19	.12	.15	-3.22	-3.96***
	Winter, Spring, Fall 1976	English 111	440	-6.51	-4.50***	-3.34	-5.08***	-1.37	-4.76***	-1.28	-3.54***

*p<.05

**p<.01

***p<.001

[1] This estimated effect was found to vary inversely with students' age.

[2] For male students.

[3] For female students.

Table 6.11

the same extent as classroom lectures did in traditional sections. These comparisons between specific features of the TICCIT system and their counterparts in lecture sections depend on parallels drawn between certain aspects of the two instructional conditions. We believe such parallels to be warranted by the advocacy of the TICCIT program as a complete and independent replacement for conventional teaching practices. Student reactions seem to demonstrate that there is still a need for instructors explaining difficult material and presenting concepts and rules.

Since the estimated treatment effects on student attitudes in mathematics courses apply to those students who completed a mathematics course under the TICCIT program, there was a restriction in the size of the student population that affected each analysis. We had to rely on entrance ability alone in identifying similar students and then estimating differences in their attitudes across conditions. The number of students completing an algebra course on the TICCIT system was so low at Alexandria that analyses of attitude data collected after the fall quarter of the 1975-76 academic year had to include all respondents to the student survey rather than just those who had completed their course requirements. Yet the pattern of treatment effects remained negative and still showed statistically significant differences on the attitude scale for system Features. In addition to a limitation in sample size, the analyses of attitude results in math courses yielded low multiple correlations. Seldom did the regression models account for as much as one-fifth of the total variance in mathematics courses.

But these factors do not invalidate the estimated treatment effects. They instead make each analysis conservative in that it becomes harder to demonstrate a statistically significant effect. This evaluation has shown such effects across courses and academic terms. Despite the amount of instructor time devoted to individual students (see Chapter 8: Faculty Acceptance and Teacher Role), students in TICCIT classes with a high student-teacher ratio perceived the individual attention given them as less than what comparable students in lecture sections reported. Furthermore, students rated specific features of the TICCIT system as less helpful in their learning than the lecture counterparts of those features. Although close in the degree of personal satisfaction with a course, students in TICCIT classes reacted less favorably to their mathematics course than did students in lecture sections of the same course.

English Courses. Student attitudes in English courses on the TICCIT system depended very much on the context of the particular course. The estimated treatment effects for TICCIT classes which sometimes included small group discussions were statistically significant and positive (see English 19 and 29 in Table 6.11). Those for TICCIT classes in which the use of the TICCIT system was at the discretion of the instructor were statistically significant and negative (see English 111 in Table 6.11). Finding significant effects in opposite directions seems to demonstrate that computer-assisted instruction does not alone guarantee any result. Instead its impact depends heavily on the manner in which we choose to apply it.

On the attitude scale representing student responses to all common statements there was a definite positive effect in English courses at Phoenix. That positive treatment effect varied inversely with students' age: younger students, in particular, reacted favorably to English courses when offered on the TICCIT system. Students in these TICCIT classes generally expressed stronger agreement with a statement about the course meeting their own needs than did students in lecture-discussion sections (see response mean for item 6 on Form 068 in Table 6.5). Furthermore, students reported feeling a greater challenge to do their best work and trying harder to learn the material in TICCIT classes (see response means for items 19 and 27, respectively, on Form 068 in Table 6.5). These differences stood behind the positive estimate of a treatment effect on the attitude scale for Course Satisfaction. The estimated treatment effect on the attitude scale for Individual Attention was also statistically significant and positive. From the student's perspective it seemed that instructors gave them more individual attention and monitored their course progress with greater concern in TICCIT classes. Here is the exception which proves the potential of the TICCIT program, set in an appropriate context, for affecting student attitudes in a positive manner.

Estimated treatment effects for English courses involving a combination of regular classroom meetings and student sessions on the TICCIT system were statistically significant and negative. On each attitude scale the difference between scores from TICCIT classes and those from lecture-discussion sections indicated more favorable student responses with traditional teaching practices. Since TICCIT classes really entailed partial use of the computer system, it may seem that these comparisons between instructional conditions unfairly take student attitudes toward a whole course given in a lecture-discussion format as a relative standard for evaluating student attitudes toward some fraction of a course conducted under the TICCIT program. But every statement included on the attitude scales for Course Satisfaction and Individual Attention did deal with the entire course and each statement appeared with the same wording in both instructional conditions. The estimated treatment effects on these two attitude scales were statistically significant and negative. When instructors decided to adopt the

TICCIT program as a secondary instructional resource, students expressed less personal satisfaction with the course and reported a decrement in the individual attention devoted to them.

Does the replication of negative results in mathematics courses as well as in an English course make the positive results found in the English courses at one demonstration site less important? The prevalence of negative estimates for treatment effects, with a large number of those effects reaching statistical significance on the attitude scales for Individual Attention and System Features, may seem to establish the impact of the TICCIT program on student attitudes. Actually the negative effects instead indicated a need to retain usual student-teacher ratios in TICCIT classes and the importance of the instructor in presenting concepts and in explaining difficult material. They perhaps also suggested the difficulty which instructors might encounter in attempting to incorporate the TICCIT program into their regular classes. The significant, positive effects remain important. They serve both as an example of the potential of the TICCIT program and as a reminder of the degree to which context can shape outcomes.

6.4 Discussion

The pattern of results in the analysis of student attitudes clearly demonstrates that affective reactions to the TICCIT program depend on the manner of its use. While the estimated treatment effects had been consistently negative for course completion rates and generally positive for student achievement, those for student attitudes changed in direction and significance as the context of TICCIT classes became different. Moreover, the changes in the estimated treatment effects on specific attitude scales fit the conditions of courses offered on the TICCIT system. This aspect of student performance highlights the importance of the conditions under which applications of computer-assisted instruction take place, especially the role played by the teacher in facilitating student learning on computers.

Actually, student reactions to courses offered under the TICCIT program were favorable. Students tended to agree with positive statements about their course (e.g., "I would recommend this course to my friends," and "Instruction in this class met my own particular needs") or about the TICCIT program (e.g., "The rule statements RULE on TICCIT made mathematical concepts easy to learn") and to disagree with negative statements (e.g., "The method of instruction for this course was too impersonal for me"). Furthermore, the TICCIT program promoted a sense of student responsibility for their own learning and made students active participants in the instructional process. However, there were differences in the attitudes of students completing courses under the TICCIT program and the attitudes of similar students in lecture-discussion sections of the same courses.

Of twelve analyses conducted for mathematics courses within academic terms, there were eleven negative estimates of treatment effects on overall student attitudes. The statistical test associated with these negative treatment effects was significant in three cases. Such results indicate that students in TICCIT classes reacted less favorably to their math course than did students of comparable ability in lecture sections. Yet students viewed the course itself and the fit of instruction in the course to their own needs nearly as favorably in TICCIT classes as in lecture sections. On the attitude scale representing students' personal satisfaction with a course there were still eleven negative estimates of treatment effects but only one was statistically significant. Why students had less positive reactions to mathematics courses under the TICCIT program becomes evident from other attitude scales.

When the student-teacher ratio in TICCIT classes was higher than that in lecture sections of mathematics courses, the majority of estimated treatment effects on the attitude scale for Individual Attention were statistically significant and negative. Students reported that they had received less individual attention in TICCIT classes, particularly in those courses which would be a student's first mathematics course at the community college. Instructors in TICCIT classes had actually devoted a greater proportion of their time to counseling individual students (see Chapter 8: Faculty Acceptance and Teacher Role). But computer-assisted instruction had also generated a greater student demand for individual attention. Faculty supervised students' final attempts at mastery tests and answered students' questions about the subject matter. Whenever a student had to wait for an instructor to become available, that student judged the individual attention to be inadequate. Although the TICCIT program indeed changed what teachers did in mathematics courses, it did not lessen a student's need for the assistance of an instructor.

The estimated treatment effects on another attitude scale, System Features, suggest the reasons for students frequently requesting instructor assistance in mathematics courses. On this attitude scale there were significant negative effects evident across colleges, courses, and academic terms. Although students found the practice problems on the TICCIT system to be as helpful in learning mathematical rules and concepts as homework exercises, they rated the rule statements and help sequences of the TICCIT program less favorably than the lecture counterparts of these system features. The TICCIT program had incorporated presentations of mathematical concepts at three levels of difficulty and explanations of problem solving with a fixed degree of detail. Neither proved to be the equivalent of traditional teaching practices. Classroom lectures and instructor explanations received higher student ratings.

English courses in which each instructor decided on the extent of student exposure to the TICCIT system showed significant, negative treatment effects on every attitude scale. These TICCIT classes really represented a different use of the TICCIT program. It was a combination of regular classroom sessions and computer-assisted instruction. But the English curriculum on the TICCIT system had been developed as an intact course. To students a mixture of learning on the computer and teaching in a classroom may be like taking a single course under two instructors with different approaches to the subject matter. There must be a careful integration of the computer and classroom curriculum in order to gain student acceptance.

The exception to these unfavorable attitude results occurred in English courses for which the TICCIT program was the primary instructional resource. In these courses on the fundamentals of grammar and the essentials of written expression, instructors sometimes adjusted the hierarchical structure of the TICCIT curriculum and often conducted small group discussions. The student-teacher ratio remained much the same as that in lecture-discussion sections. Under these conditions there were more positive student attitudes in TICCIT classes than in lecture-discussion sections. The estimated treatment effect on overall student attitudes was positive and statistically significant. Students in TICCIT classes, particularly younger students, expressed a greater degree of personal satisfaction with their course than did similar students in regular sections. And students in TICCIT classes reported a greater degree of individual attention had been devoted to them. This course format apparently drew on the strengths of the TICCIT program in providing practice exercises, the instructors in elaborating on difficult material and motivating students, and group discussions in promoting personal interactions. The results were positive student attitudes and higher posttest performance (see Chapter 5: Student Achievement).

Computer-assisted instruction by itself neither guarantees favorable student attitudes nor meets all student needs for further elaboration and clarification of the subject matter. Especially with a student population as heterogeneous as that of community colleges it would be impractical to attempt developing a tutorial computer application capable of meeting the needs of all students. Instructors must be available for explaining what students find difficult to understand. Moreover, a computer system that supports the equivalent of full college courses may relieve instructors of their usual duties, but it also generates new demands which preclude any dramatic increase in usual student-teacher ratios. Yet the TICCIT program has shown that computer-assisted instruction can, under the proper conditions, both facilitate student learning and promote positive student attitudes.

Chapter 7

Student Activities

Our study of TICCIT's impact on student activities was intended to be descriptive and somewhat exploratory. Unlike other aspects of student performance where the nature of a positive effect may be clear, it is often difficult to identify and document a desirable outcome with regard to activities. A program might encourage students to consider taking further courses or seek a job related to the subject matter, but the real test of such plans would be in their successful fruition. Or a curricular program would perhaps be conducive to more frequent discussions between a student and an instructor only to detract from the net time students devoted to learning the subject matter. And with an innovative computer-based curriculum such as the TICCIT program the most pertinent question to raise might simply be the matter of what students do on the computer system so as to learn.

This chapter has two major sections. The first section is similar to earlier chapters in that it covers student activities in a comparative manner. Data on the extent of students' interpersonal contacts related to the courses, the amount of time devoted to course studies, and their plans for further courses and future work will be presented for students in both TICCIT classes and lecture-discussion sections. However, there is no attempt made to estimate treatment effects on such activities since this section is meant to be descriptive. The second section deals with the interaction of student and computer. It concerns what happens to a student at a TICCIT terminal. Primarily that description follows from student use of TICCIT's learner control features. Also presented is some evidence on the relationship between time spent on the computer system and learning. Our attempt to explore the student-computer interaction on the TICCIT system is necessarily descriptive as it relates only to TICCIT classes.

7.1 Activities across Comparison Groups

Part of the student surveys (see Appendix F) called for responses to questions about specific activities related to a course and possibly affected by the TICCIT program. The questions themselves reflected three central issues involved in student activities. Firstly, its developers hoped that the TICCIT program would result in a positive student approach toward the subject matter. This would be shown by students electing to take further courses in the subject or planning to enter a related job. Actually data on subsequent course enrollment appear elsewhere (see Chapter 4: Course Completion Rates and Appendix N), and here we report students' intentions as expressed on our survey. Secondly, much criticism of instructional technology has arisen from a concern about the impersonal nature of media like the computer. Learning by computer, presumedly, would detract from students' personal contacts with other students or their instructors. Again pertinent data on students' own perceptions can be found in another chapter (see Chapter 6: Student Attitudes); this chapter includes student estimates of the frequency of their course-related interpersonal contacts. And, thirdly, it has been said that the amount of time students devote to studying is a critical variable in their learning. Within this chapter we give a basic description of how students allocated their study time and later consider the relationship between time and learning for students on the TICCIT system.

Summaries of student responses to questions about their course activities appear in Appendix S. Two points should be kept in mind while reviewing the data in this appendix and the tables which follow: only those students who anticipated completing a course responded to the surveys, except for math courses at Alexandria where all students attending classes at the end of a quarter responded; and these data merely repeat student self-reports in summary form. Thus the groups within each instructional condition may differ with respect to a critical variable such as entrance ability, or the self-reports may be highly unreliable. There would be strong alternative explanations for any difference apparently due to the mode of instruction.

Before presenting results from a few selected courses it might be useful to consider some irregular patterns across courses. At Phoenix, for example, the TICCIT program apparently made the prospect of further courses in math and a job related to math seem attractive to students in Math 007 during the fall semester but not the spring. Similarly, a higher percentage of students in TICCIT classes than lecture sections of Math 31 at Alexandria indicated an intention to pursue further math courses as a result of their course experiences in the fall and spring quarters but not in the winter. Most often students in English classes on the TICCIT system estimated more time spent on their course studies than did students in lecture-discussion classes. But the opposite result, students spending less study time in TICCIT classes, prevailed among math courses.

It would seem that changes in the direction of differences between conditions require some explanation. In our opinion seeking underlying reasons for inconsistent student self-reports would not be fruitful. Such differences might easily be attributed to the unreliability of the estimates given by students or a characteristic unevenly distributed in the comparison groups. Indeed, where changes in the direction of comparisons do occur, they tend to be small in relation to the number of students involved or the standard deviation associated with the activity.

Tables 7.1 through 7.4 present selected results for student activities. These summaries correspond to the questions on the student survey explicitly concerned with plans, interpersonal contacts, and amount of time devoted to a course. A course in each subject at both colleges is represented.

Student Activity Survey
Item Responses across Instructional Conditions
Phoenix College
Math 007
Fall Semester, 1975

Item Stems	TICCIT (N = 27)			Lecture (N = 134)		
	Item Number (Form 035)	N	Percent	Item Number (Form 040)	N	Percent
Plans for further courses or work in math:						
At the beginning of this term did you plan to take more than just the introductory course(s) in math?	31	Yes-17	63.0	27	102	76.7
		No-10	37.0		31	23.3
When you finish the introductory course(s) do you plan to take any more advanced courses in math?	30	Yes-21	77.8	26	111	85.4
		No- 6	22.2		19	14.6
Has your experience in this course:	32			28		
· encouraged you to take further courses in math?		13	48.1		56	42.7
· discouraged you about taking further courses in math?		4	14.8		14	10.7
· had no effect on your plans for further courses in math?		10	37.0		61	46.6
Is a job related to math more appealing to you now than it was at the beginning of this course?	33	Yes- 9	33.3	29	46	35.4
		No-18	66.7		84	64.6
Frequency of interpersonal contact: (see explanation of codes given below):		Mean	sd		Mean	sd
During this semester about how often did you:	34			30		
· meet with the instructor [or proctor] for this course, outside of class, to discuss your classwork or anything else related to the course?	a	1.22	.51	a	1.26	.52
· meet with the instructor for this course to discuss personal or academic matters NOT specifically related to the course?	b	1.04	.19	b	1.05	.26
· discuss questions related to the course with fellow students?	c	1.74	.81	c	1.83	.71
· seek the help of a tutor for this course?	d	1.37	.69	d	1.15	.45
· use library resources in connection with your work in this course?	e	1.15	.37	e	1.06	.30
· want to use the TICCIT system when it wasn't available?	f	1.93	.83			
Time spent on course:						
Approximately how many hours per week did you spend:	35			31		
· working on the TICCIT system/attending classes for this course?	a	6.41	3.02	a	2.93	.50
· in small group discussions about this course (outside of class)?	b	.45	1.10	b	.35	.81
· doing work for this course on your own away from TICCIT/working on homework assignments?	c	1.10	2.08	c	3.51	2.47
· in total for this course?	d	9.01	5.20	d	6.66	2.65

Item Coding (Form 035): Item 34(a)-(f)
3 = Quite Often
2 = Occasionally
1 = Almost Never

Table 7.1

Student Activity Survey
Item Responses across Instructional Conditions
Northern Virginia Community College
Math 31
Fall Quarter, 1975

Item Stems	TICCIT (N ≅ 46)			Programmed (N ≅ 21)			Lecture (N ≅ 44)		
	Item Number (Form 063)	N	Percent	Item Number (Form 064)	N	Percent	Item Number (Form 062)	N	Percent
Plans for further courses or work in math:									
At the beginning of this term did you plan to take more than just the introductory course(s) in math?	31	Yes-27	60.0	31	Yes-14	66.7	27	23	52.3
		No-18	40.0		No- 7	33.3		21	47.7
When you finish the introductory course(s) do you plan to take any more advanced courses in math?	30	Yes-37	80.4	30	Yes-16	76.2	26	13	31.0
		No- 9	19.6		No- 5	23.8		29	69.0
Has your experience in this course:	32			32			28		
• encouraged you to take further courses in math?		21	45.7		11	52.4		19	43.2
• discouraged you about taking further courses in math?		3	6.5		0	0.0		3	6.8
• had no effect on your plans for further courses in math?		22	47.8		10	47.6		22	50.0
Is a job related to math more appealing to you now than it was at the beginning of this course?	33	Yes-18	40.0	33	Yes- 6	30.0	29	14	32.6
		No-27	60.0		No-14	70.0		29	67.4
		Mean	sd		Mean	sd		Mean	sd
Frequency of interpersonal contact: (see explanation of codes given below):									
During this quarter about how often did you:	34			34			30		
• meet with the instructor [or proctor] for this course, outside of class, to discuss your classwork or anything else related to the course?	a	1.45	.66	a	1.19	.40	a	1.60	.66
• meet with the instructor for this course to discuss personal or academic matters NOT specifically related to the course?	b	1.09	.29	b	1.19	.40	b	1.16	.37
• discuss questions related to the course with fellow students?	c	1.73	.81	c	1.48	.60	c	1.93	.84
• seek the help of a tutor for this course?	d	1.20	.50	d	1.05	.22	d	1.10	.30
• use library resources in connection with your work in this course?	e	1.13	.40	e	1.19	.40	e	1.07	.26
• want to use the TICCIT system when it wasn't available?	f	1.86	.69						
Time spent on course:									
Approximately how many hours per week did you spend:	35			35			31		
• working on the TICCIT system/attending classes for this course?	a	6.89	2.18	a	4.64	.52	a	4.63	.80
• in small group discussions about this course (outside of class)?	b	.25	.73	b	.14	.36	b	.60	1.04
• doing work for this course on your own away from TICCIT/working on homework assignments?	c	1.40	1.68	c	4.36	4.07	c	5.01	3.36
• in total for this course?	d	8.25	3.20	d	10.07	5.53	d	10.15	4.91

Item Coding (Form 063): Item 34(a)-(f)

3 = Quite Often
2 = Occasionally
1 = Almost Never

Table 7.2

Student Activity Survey
Item Responses across Instructional Conditions
Phoenix College
English 19 and 29
Fall Semester, 1976

Item Stems	TICCIT (N ≅ 109) Item Number (Form 068)	N	Percent	Lecture (N ≅ 170) Item Number (Form 067)	N	Percent
Plans for further courses or work in English:						
At the beginning of this term did you plan to take more than just the introductory		Yes-67	61.5		116	66.3
course(s) in English?	34	No-42	38.5	29	159	33.7
When you finish the introductory course(s) do you plan to take any more advanced		Yes-96	88.1		159	90.9
courses in English?	33	No-13	11.9	28	16	9.1
Has your experience in this course:						
• encouraged you to take further courses in English?		56	51.4		103	58.9
• discouraged you about taking further courses in English?	35	1	.9	30	5	2.9
• had no effect on your plans for further courses in English?		52	47.7		67	38.3
Is a job related to English more appealing to you now than it was at the beginning of		Yes-57	52.3		83	48.3
this course?	36	No-52	47.7	31	89	51.7
		Mean	sd		Mean	sd
Frequency of interpersonal contact: (see explanation of codes given below):						
During this semester about how often did you:	37			32		
• meet with the instructor [or proctor] for this course, outside of class, to discuss your classwork or anything else related to the course?	a	1.51	.70	a	1.37	.58
• meet with the instructor for this course to discuss personal or academic matters NOT specifically related to the course?	b	1.18	.43	b	1.19	.43
• discuss questions related to the course with fellow students?	c	1.99	.75	c	1.85	.73
• seek the help of a tutor for this course?	d	1.45	.69	d	1.12	.39
• use library resources in connection with your work in this course?	e	1.19	.46	e	1.60	.68
• want to use the TICCIT system when it wasn't available?	f	1.60	.78			
Time spent on course:						
Approximately how many hours per week did you spend:	38			33		
• working on the TICCIT system/attending classes for this course?	a	5.43	5.05	a	2.91	.71
• attending regular class meetings, without TICCIT, for this course?	b	1.17	2.84		—	—
• in small group discussions about this course (outside of class periods)?	c	.26	.72	b	.51	.99
• doing work for this course on your own away from TICCIT/working on homework assignments?	d	1.51	2.58	c	3.39	3.00
• in total for this course?	e	9.37	10.54	d	6.77	5.30

Item Coding (Form 068): Item 37(a)-(f)
3 = Quite Often
2 = Occasionally
1 = Almost Never

416

417

Table 7.3

Student Activity Survey
Item Responses across Instructional Conditions
Northern Virginia Community College
English 111
Fall Quarter, 1976

Item Stems	TICCIT (N ≅ 115)			Lecture (N ≅ 74)		
	Item Number (Form 066)	N	Percent	Item Number (Form 065)	N	Percent
Plans for further courses or work in English:						
At the beginning of this term did you plan to take more than just the introductory course(s) in English?	34	Yes-80	69.6	29	45	60.8
		No-35	30.4		29	39.2
When you finish the introductory course(s) do you plan to take any more advanced courses in English?	33	Yes-97	83.6	28	59	80.8
		No-19	16.4		14	19.2
Has your experience in this course: (see explanation of codes given below):	35			30		
• encouraged you to take further courses in English?		40	34.8		43	58.1
• discouraged you about taking further courses in English?		11	9.6		3	4.1
• had no effect on your plans for further courses in English?		64	55.7		28	37.8
Is a job related to English more appealing to you now than it was at the beginning of this course?	36	Yes-51	45.1	31	35	47.3
		No-62	54.9		39	52.7
		Mean	sd		Mean	sd
Frequency of interpersonal contact:						
During this semester about how often did you:	37			32		
• meet with the instructor [or proctor] for this course, outside of class, to discuss your classwork or anything else related to the course?	a	1.45	.62	a	1.75	.68
• meet with the instructor for this course to discuss personal or academic matters NOT specifically related to the course?	b	1.25	.49	b	1.17	.37
• discuss questions related to the course with fellow students?	c	2.14	.69	c	2.11	.72
• seek the help of a tutor for this course?	d	1.21	.47	d	1.21	.47
• use library resources in connection with your work in this course?	e	1.49	.73	e	1.85	.63
• want to use the TICCIT system when it wasn't available?	f	1.99	.80			
Time spent on course:						
Approximately how many hours per week did you spend:	38			33		
• working on the TICCIT system/attending classes for this course?	a	5.19	3.32	a	5.01	.98
• attending regular class meetings, without TICCIT, for this course?	b	3.05	1.70		——	——
• in small group discussions about this course (outside of class periods)?	c	.69	1.17	b	1.39	2.57
• doing work for this course on your own away from TICCIT/working on homework assignments?	d	3.59	4.01	c	6.59	5.39
• in total for this course?	e	13.74	9.00	d	14.40	7.80

Item Coding (Form 066): Item 37(a)-(f)
3 = Quite Often
2 = Occasionally
1 = Almost Never

Table 7.4

Plans for Further Courses and Future Work. For a sizeable percentage of students experience in a course had no effect on their plans. At least one-third and often one-half of the students in a course, regardless of the particular instructional condition, reported that their experience had no effect on their plans for further courses in the subject. Seldom did a single course discourage students from pursuing further courses: such a negative effect on student plans occurred infrequently although at times reached approximately an eighth of the students responding. Of course we should also consider program outcomes with regard to course completion in interpreting these data obtained primarily from those students who completed the requirements for course credit.

Typically exposure to a course on the TICCIT system encouraged a percentage of students to take further courses comparable to the percentage already encouraged through lecture-discussion practices. A similar conclusion may be drawn from student responses to a question about another dimension of approach toward the subject matter. Course experiences made a job related to the subject matter seem more attractive to roughly equal percentages of students in each instructional condition. Among students completing a course, then, it would appear that the impact of the TICCIT program on plans for further courses and future work was consistent with that of control classes taught in a conventional manner.

Interpersonal Contacts. Perhaps unexpected was the fact that students reported as much interpersonal contact in TICCIT classes as lecture-discussion sections. In both conditions discussions of course questions with fellow students was the most frequent type of contact. By contrast, students almost never sought the help of a tutor or met with their instructor to discuss matters outside formal course concerns. Considering the obvious differences between a classroom environment and a computer system for teaching, there was remarkable similarity in the frequency of students' interpersonal contacts. Admittedly, our scale for responses to such questions was quite limited and the questions about contact with instructors dealt just with meetings outside of class. Still the data tend to counter arguments about the impersonal nature of computer applications in education.

There was one appreciable difference in these frequency estimates that seemed to follow from the instructional condition. But it concerned student use of resources rather than personal contacts. Students in English classes on the TICCIT system reported less frequent use of library resources in connection with their course work than did students in lecture-discussion classes. This may reflect a qualitative difference in instruction between the two conditions or the TICCIT system's capacity to store relevant material such as examples of writing.

It might also be noted, with regard to resources, that the majority of students in TICCIT classes reported occasionally wanting to use the computer system when it wasn't available. Yet the hours of system operation closely matched the schedule of regular classes. Limited hours of availability would not seem to be the reason behind these student responses. Instead it was probably the physical location that acted as a constraint on availability. Students had to be on campus in order to study on the TICCIT system while textbooks from regular classes could be taken home.

Study Time. Across courses students in TICCIT classes spent most of their study time working on the TICCIT system while students in lecture sections reported most of their time given to working on homework assignments. So much time was devoted to homework assignments in lecture sections of math courses that students in TICCIT classes spent less total time on their course studies.

Also, math courses courses on the TICCIT system adhered closely to the concept of mainline instruction: the amount of time spent working on the TICCIT system accounts for nearly the total time spent on a course. Table 7.1 and Table 7.2 represent the worst cases in this regard since the computer system was at its most incomplete and unreliable stage of the demonstration period in the fall academic term of 1975. Other cases contained in Appendix S better show math courses' adherence to mainline instruction. For example, 5.93 hours were spent on the TICCIT system out of the estimated 6.49 total hours per week reported for Math 007 in the spring semester, or approximately 90%.

Students in TICCIT sections of English courses reported spending more time than students in lecture-discussion classes. An English course on the TICCIT system actually combined computer-assisted instruction with regular class meetings. At Phoenix students met approximately one hour per week for group discussions independent of the TICCIT system. At Alexandria the equivalent of three classroom sessions per week was combined with extensive use of the TICCIT program. And these English classes on the TICCIT system also had writing assignments. Except for English 111 in the fall quarter, the combination of computer sessions, group meetings and homework assignments resulted in a heavier study load for students in TICCIT classes. The estimates of study time given for English courses show that this application of the TICCIT program began to depart from the developers' original concept of mainline instruction. However, the greatest portion of study time in TICCIT classes was spent on the computer system in both math and English courses.

7.2 Student Interaction with the TICCIT System

Among the distinctive features of the TICCIT program were the concepts of learner control and mainline instruction. Learner control gave students an opportunity to guide their own instruction and exercise control over the learning strategies available on the TICCIT system. Mainline instruction meant that the computer system served as the primary resource for teaching. Much depended, then, on what happened when a student sat down at a TICCIT terminal. This student-computer interaction would to a great extent determine the outcomes of the TICCIT program.

Little was known about what might take place between a student and the TICCIT system. The instructional design of the program was innovative and experimental. Yet the developers had to commit themselves to that design in the hardware, software, and courseware of the TICCIT system in order to meet their production schedule. The importance and uncertainty of student-computer interactions prompted us to take a close look at this process. We hoped that data on student use of the TICCIT system would be helpful in understanding the program's outcomes, in refining subsequent versions of the system, and perhaps in designing similar instructional systems.

7.2.a Observations

When the demonstration began in the fall term of 1975, observing student use of the TICCIT system was the simplest and most direct method for gathering data. Watching individual students as they worked through TICCIT materials enabled us to look closely at the process whose outcomes were under evaluation. Observations let us know what the instructional design of the TICCIT system meant, in operational terms, for the student. But this procedure for collecting data on student-computer interactions also required a substantial investment of staff resources in observing students and developing an appropriate form for recording data. It took at least half of an hour to complete one observation. And two semesters of pilot trials preceded the observations reported below.

Sampling. All students observed in the fall academic term were enrolled for the same course. That course was Beginning Algebra at Phoenix (Math 007) and Algebra I at Alexandria (Math 31). Our observers randomly selected 84 students at Phoenix and 26 at Alexandria to track throughout the term. It was felt that only a series of observations on the same student group would permit us to detect changes in learning strategies as a function of experience. There were five observation cycles within the academic term. Each cycle lasted two or three weeks and gave us a minimal time period for completing one observation on every student in the original sample.

Observation Record. The form used in recording data on student-computer interactions was the product of 121 trial observations and some extensive revisions. Its focus was on obtaining a descriptive record of student sessions at a TICCIT terminal. Questions requiring a subjective judgment on the part of the observer (e.g., attentiveness of the student) were eliminated. Coding became straightforward and tended to follow an individual student's choices among the TICCIT options for learner control. The directions given to observers and the form completed during observations appear in Appendix G.

The observation record had an explicit coding scheme for describing student-computer interactions. Through codes specific to each question the observers noted what materials students brought with them to the terminals, whether a system failure occurred during the observation, how students used learner control, and what type of assistance students sought beyond that provided by the computer system. The codes for these questions were specific enough to insure a high degree of interobserver agreement. Indeed the average percentage of cases in which our two observers assigned the same code exceeded 90% in trials conducted to test the form's reliability (see Chapter 2: Methods and Measurement). As for the accuracy of these descriptions, we later note the consistency of results whether obtained by observing students at terminals or recording student key strokes automatically by computer.

Results. The size of our sample dwindled with each observation cycle. Of the 84 students in the initial sample at Phoenix there was a complete set of five observations for 33 students. The number of observations fell steadily across cycles: there were 84 observations in the first cycle, then 62, 57, 45 and finally 40. Similarly, only seven students originally selected at Alexandria had been observed in each of the five cycles. Part of this reduction in sample size may be attributed to formal course withdrawals. Another part was probably the result of our difficulty in locating students at terminals since there was not yet any mechanism for identifying students on the system. But most of the reduction seems a function of the self-paced nature of the TICCIT program.

Students chose their own schedules for working on the TICCIT system. This meant that they often worked outside of their assigned time periods or let weeks pass without attending to their studies under the TICCIT program. The tendency to neglect studies is better evident in the completion rates for math courses as a high percentage of reenroll grades (see Chapter 4: Course Completion Rates) and in the progress reports generated by computer as the date a student last worked on the TICCIT system (see Figure 7.2). Irregular attendance patterns greatly reduced the number of observations done within an academic term. The completion rates for English courses on the TICCIT system, however, suggest that sample size would have been more stable had we observed students in TICCIT English classes rather than math.

The data from each college had to be aggregated in such a way that a descriptive summary would be fair and representative. For the Phoenix observations it was reasonable to aggregate the data according to the five observation cycles. There were so few complete sets of observations for Alexandria that data had to be collapsed into three time periods in order to attain nearly 20 full sets. This left us with only 64 of the 109 observations done at Alexandria: 20 observations were set aside since they were part of interobserver reliability trials and 25 others became duplicates in collapsing data into three cycles.

Contrary to what would be expected (see Bunderson, 1975; Merrill, 1975), we found no remarkable differences either across observation cycles or between those students with complete sets of observations and others with fewer observations. If learning strategies improved as students gained experience with the TICCIT system or if certain strategies gave students a higher probability for success (i.e., course completion), such differences were not evident from our observation record despite its rather comprehensive coverage. Instead the most obvious trait shared by students completing a course in introductory algebra, aside from pretest scores higher than their classmates (see Chapter 4: Course Completion Rates and Chapter 5: Student Achievement), was regular attendance.

Table 7.5 is a summary of student-computer interactions. It follows the major sections of the observation record, beginning with "Materials." Almost all students at terminals brought some paper, whether in a notebook or just loose sheets, for taking notes and working problems. But very few students had the course manual prepared by TICCIT's developers. Faculty had recommended that students purchase the course manual in the summer semester but did not do so again in the fall. Neither did students bring math textbooks to their sessions on the TICCIT system. They relied instead on whatever material the computer presented to them.

Student Interaction with the TICCIT System:
Summary of Observations
Alexandria and Phoenix
Math 31 and Math 007
Fall Term 1975-76

	Phoenix		Alexandria		Total	
	Number of Observations	Percent	Number of Observations	Percent	Number of Observations	Percent
Total number of observations	288	100	64	100	352	100
Materials Present						
Course manual	9	3	1	1	10	3
Note pad, notebook	127	44	43	67	170	48
Work sheets, loose paper	153	53	18	28	171	49
Math textbook	0	0	0	0	0	0
Other (e.g., calculator)	6	2	2	3	8	2
System Failures						
Frequency	21	7	15	23	36	10
Duration	107 min.	2[a]	50 min.	4[a]	157 min.	2[a]
Learner Control						
Sequence:						
none observed	177	61	43	67	220	63
generality (RULE) first	81	28	17	27	98	28
instance (EXAMPLE, PRACTICE) first	30	10	4	6	34	10
RULE use:						
frequency--						
0	180	63	35	55	215	61
1	62	22	12	19	74	21
2	22	8	7	11	29	8
3	17	6	5	8	22	6
4	7	2	5	8	12	3
pace--						
wrote out RULE completely	7	2	2	3	9	3
took some notes on RULE	22	8	2	3	24	7
repeated the same RULE	3	1	3	5	6	2
read RULE at a moderate pace	71	25	22	34	93	26
merely glanced at RULE	5	2	0	0	5	1
EXAMPLE use:						
frequency--						
0	236	82	33	52	269	76
1-5	42	15	16	25	58	16
6-10	6	2	6	9	12	3
11-15	0	0	8	12	8	2
16-	4	1	1	1	5	1
pace--						
wrote out EXAMPLE in full	6	2	3	5	9	3
took some notes on EXAMPLE	4	1	1	1	5	1
repeated the same EXAMPLE	0	0	0	0	0	0
read EXAMPLES at a moderate pace	19	7	12	19	31	9
merely glanced at EXAMPLES	23	8	15	23	38	11
PRACTICE use:						
frequency--						
0	19	7	2	3	21	6
1-5	132	46	25	39	157	45
6-10	93	32	15	23	108	31
11-15	32	11	10	16	42	12
16-	12	4	12	19	24	7

Table 7.5(a)

	Phoenix		Alexandria		Total	
	Number of Observations	Percent	Number of Observations	Percent	Number of Observations	Percent
pace--						
more than 5 minutes per problem	40	14	13	20	53	15
3-5 minutes per problem	45	16	5	8	50	14
2-3 minutes per problem	49	17	13	20	62	18
1-2 minutes per problem	82	28	15	23	97	28
less than 1 minute per problem	53	18	16	25	69	20
HELP use:						
frequency--						
did not use HELP	122	42	18	28	140	40
used HELP sometimes with incorrect responses to problems	47	16	16	25	63	18
used HELP almost always with incorrect responses to problems	113	39	10	16	123	35
used HELP in other ways	6	2	20	31	26	7
pace--						
took notes on HELP	18	6	13	20	31	9
repeated the same HELP	6	2	1	1	7	2
compared solutions step-by-step	48	17	21	33	69	20
compared solutions quickly	71	25	10	16	81	23
merely glanced at the answer	23	8	1	1	24	7
Use of other TICCIT features:						
OBJECTIVE	131	45	26	41	157	45
ADVICE	67	23	23	36	90	26
Introduction	13	5	3	5	16	5
Review	4	1	5	8	9	3
Survey	4	1	0	0	4	1
Requests for Assistance						
Frequency	87	30	29	45	116	33
Questions about content	51	18	13	20	64	18
Questions about procedures	36	12	16	25	52	15
Response by--						
instructor	20	7	14	22	34	10
proctor	33	11	5	8	38	11
observer	29	10	6	9	35	10
staff	7	2	4	6	11	3
Type of response--						
explanation or elaboration	14	5	11	17	25	7
specific information	58	20	12	19	70	20
inadequate or respondent unable to provide assistance	16	6	4	6	20	6
none	1	0	2	3	3	1

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[a] This percentage assumes that each observation lasted 20 minutes. Most observations actually took longer than that amount of time. Several others, however, had to be rescheduled due to interruptions in system service of over 15 minutes.

Table 7.5(b)

System failures occurred fairly frequently in the fall term of the 1975-76 academic year. Their frequency actually interferred with collecting data at Alexandria in that several observations had to be discarded due to interruptions in service. And at Phoenix breakdowns of the computer system were seen as disruptions in student learning (see Chapter 6: Student Attitudes). Yet the time lost to computer malfunctions amounted to only about two percent of total operating time. It was the frequency rather than the duration of system failures that distracted students. In later terms, system reliability did improve, along with student perceptions of computer breakdowns as a less disruptive influence on their learning (see, for example, the mean responses across quarters to item 15 on the student survey for English 111, reported in Appendix R).

Most often there was no sequence observed for students' use of learner control. This simply reflects the fact that observations most often started when students were in the midst of their work on a segment. Students had to choose an order of presentation for the material within each segment on the TICCIT system. They might study the general statement of a mathematical rule prior to looking at examples of its application or trying practice problems requiring its use. This deductive sequence, RULE followed by EXAMPLE or PRACTICE, was the dominant approach in cases where a sequence was apparent. That students should prefer to study rules or concepts before applications of those generalities stands to reason: such a sequence is consistent with the order of presentation already familiar to students from their textbooks.

The low incidence of observed sequences meant that either rules or instances were absent from a high percentage of observations. It was the rule. The number of observations in which students failed to access a rule statement (215) closely corresponds to the number without a recorded sequence (220). This does not imply that students disregarded generalities. About one-fourth of the cases with access to rules involved writing out the generality or taking notes on it for later reference. The lack of rule use, however, is indicative of its importance relative to the other components of learner control. When students resumed work on a segment left incomplete from their last session, they seldom referred back to a rule statement.

Student use of examples accounted for even fewer choices among TICCIT's options for learner control. But here approaches differed by college. Fewer than one-fifth of the Phoenix observations had some access to example files while nearly one-half of Alexandria data shows use of examples. Perhaps students at Alexandria were following the sequence recommended to them by instructors as a default procedure when in doubt about a reasonable approach (i.e., RULE-EXAMPLE-PRACTICE), while those at Phoenix employed a combination of TICCIT features (i.e., PRACTICE together with HELP) that gave essentially the same display as an example. At both colleges the dominant manner of students' use of examples was merely to glance at these instances of rule applications. It would therefore seem that examples hardly represented the real substance of the TICCIT curriculum. Indeed, their function could easily be fulfilled by a combination of other learner control options.

To a student the most useful component of TICCIT's instructional design was the practice problem. It was the feature most often selected by students: 94% of our observations indicated some use of the PRACTICE option. Apparently students chose to learn by doing. This mode of learning also represented an efficient use of the TICCIT system. In trying to solve problems, students received prompt feedback on their solutions and, when incorrect, could request a detailed explanation of the proper solution process. That over half of the observations included requests for additional explanation, available through the feature called HELP, indicates the importance of these two components of TICCIT's learner control.

However, there was a difference between colleges in student use of the system's help. Students at Phoenix referred to HELP quite frequently as an explanation for solutions to practice problems and, maybe, as a replacement for the example function which illustrates rule applications. Students at Alexandria tended to use HELP in much the same manner, but nearly a third of our observations there involved the use of HELP with correct as well as incorrect solutions to practice problems. Even if they had solved a problem properly, students turned to the system's solution as a readily available check for their own answer and then compared the two solutions. This would seem to point to the usefulness of feedback both in confirming correct responses and providing remediation for incorrect responses (see Kulhavy, 1977).

When the type of assistance available on the TICCIT system was inadequate or inappropriate, students sought help from their instructors or proctors. There was a feature of the TICCIT design intended to provide advice on learning strategies and counsel students on their course progress. But students soon became wary of the recommendations given as part of ADVICE after, for example, taking a lesson test as suggested and failing to attain a score above TICCIT's mastery criterion. The data from Phoenix reflect this wariness as ADVICE was seen in 29% of the observations in the first two cycles and 13% in the last two. Students did, however, find the summary of their status helpful, judging from their attention to this part of the ADVICE display and the overall incidence of ADVICE in our observations. It told them succinctly what TICCIT features they had already seen (i.e., versions of generalities and instances at different difficulty levels) as well as what options of the learner control might facilitate their learning. Despite the availability of HELP as a further explanation of the subject matter and ADVICE for assistance in learning strategies, students asked questions in about one-third of the student-computer interactions.

Requests for assistance, unlike other aspects of the student-computer interactions, changed dramatically across observation cycles. Initially fewer than half of the questions were about content. Most questions concerned procedures for operating the TICCIT system. The responses to these requests were typically limited to the specific information students needed in order to proceed. Toward the end of the term there were far fewer requests for assistance and most raised points related to the subject matter. Students had mastered the procedures for learner control and by then represented a more select and capable group in terms of their content knowledge. Sometimes a specific response was sufficient for the student's question but nearly as often it required elaboration of the TICCIT coverage by an instructor.

Generally, these results agreed with those obtained from pilot trials in earlier semesters. The one notable exception was a lower frequency of RULE use than had been observed previously, less than 38% in these fall observations at Phoenix as opposed to over 50% in the preceding spring and summer terms. This inconsistency might be due to the earlier necessity for students to rely on generalities since other components of the courseware were incomplete, or it might indicate an idiosyncrasy of the fall data. Neither interpretation would alter the basic description that emerges from these data.

The cornerstone of the TICCIT system appears to be the practice problems. While the rules and the examples of their application might easily be presented in another format, practice problems call the computer capabilities inherent to the TICCIT system into play. It was in solving practice problems that students received feedback on their solutions and requested additional explanations available on the system. It was also with practice problems that the widest spread occurred in the frequency of student usage of a learner control feature. And the usefulness of practice problems evident from student choice of this option fits well in the context of other outcomes. It is consistent with the positive TICCIT effects on student achievement, specifically those regarding the solution of routine problems in mathematics and, as shown from our objective test of writing skills, the identification and correction of sentence errors in English composition (see Chapter 5: Student Achievement). Also, PRACTICE was the one system feature that received high ratings by students both in comparison to its closest counterpart in lecture classes (i.e., homework assignments) and contrasted with ratings of other components of TICCIT's learner control (see Chapter 6: Student Attitudes).

It may seem that practice problems represent an elementary application of sophisticated computer capabilities. But such applications work: their results indicate that educational effectiveness is not a direct function of technical sophistication (see Suppes & Morningstar, 1969; Vinsonhaler & Bass, 1972). The enigmas of educational psychology, such as the diagnosis and remediation of student difficulties in learning, should represent enough of a challenge to occupy us. The TICCIT system attempted to identify and anticipate student difficulties through its explicit content structure and the isolation of critical attributes in generalities. Practice problems followed from these attributes and adhered to the map for content structure. Each problem had feedback on student responses, and an explanation of the correct solution process was available. It would seem that the predominant importance of the practice problem may be the reason for our failure to record any differences in students' learning strategies, although there were achievement-treatment interactions for course completion and achievement as program outcomes.

7.2.b On-line Data

After the fall academic term of 1975 computer programs generated detailed reports on the nature of student interactions with the TICCIT system. Direct observations then became a redundant and expensive use of staff resources in the evaluation. Our observers instead concentrated on describing general class conditions (see Chapter 3: Implementation of the TICCIT Program) and documenting instructor activities (see Chapter 8: Faculty Acceptance and Teacher Role). We relied on reports produced on the TICCIT computer system to meet our needs for data on student use of learner control functions. These reports were counts of the number of times a student referred to each feature in TICCIT's instructional design (see Figure 1.2). Additional on-line data were available from progress reports which gave a summary of a student's course status in terms of lessons passed and time spent on the TICCIT system.

Learner Control Functions: Course Summaries. The most striking feature of the on-line data summaries is the abundance of numbers in them. But there is descriptive evidence to be gleaned from the numbers. The particular course summary for student use of learner control functions given in Figure 7.1 illustrates several points. This summary was taken from system data records maintained for English 111 at Alexandria during the fall quarter of the 1976-77 academic year. It includes data on student-computer interactions gathered a full year after our observations in an application of the TICCIT program to a quite different content domain. Despite the abundance of entries, this figure represents only a partial summary. It covers six units of the TICCIT curriculum on composition (see Appendix B).

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USE OF LEARNER CONTROL FUNCTIONS -- LESSON AND UNIT TOTALS          DATE: 12/27/76
NORTHERN VA COMMUNITY COLLEGE

COURSE #111
                                                                  X                                           #TST TEST ATTEMPT       TIME
UN LS   MAP  OBJ  ADV GTOT     G   HG   EZ   HD XTOT   XE    XM  XHD  HLP  QTOT   QE    QM  QHD QHLP   Q+   Q- ITEM   1    2    3   HH/MM/SS
 6  7   465  212  291  206   125   17   26   38  495  495     0    0    0  4958 4958     0    0   11 1068  235    0    0    0    0   20 13  2
 6  8   195  114   99  142    95   16   14   17  360  360     0    0    1  1867 1867     0    0   10  556  115    0    0    0    0   14 41 19
 6  9   149   65  108   79    46   17   10    6  567  567     0    0    5   679  679     0    0   39  465  214  244   25    9    1   13 39 52
 6 10   303  211  149  335   174   68   52   41 2023 2023     0    0    7  1427 1427     0    0   65 1228  194  138   22    0    0   15  2 58
 6  0  1947 1077 1201 1142   662  163  155  162 4533 4533     0    0   28 1616416164     0    0  665 5524 1206  532   60   13    1  125 50 51

 7  1   265  118  226   97    42   26   16   13  253  149    70   34    2   532  201   200  131   35  380  140  222   25   10    1   41 50 50
 7  2   454  320  183  278   153   48   52   25  665  545    62   58   44   458  338    86   34   82  293  132    0    0    0    0   58 48 43
 7  3   407  341  362  587   290  101  117   79 1274  984   183  107   19  2984 1726   683  575  165 2018  720  168   29    1    3   73 40 23
 7  0  1126  779  771  962   485  175  185  117 2192 1678   315  199   65  3974 2265   969  740  282 2691  992  390   54   11    4  174 19 56

 8  1   950  584 1382 1254   619  241  219  175 3464 2381   459  624   39 10671 5471  2076 3124  599 7167 3380  980   77   29   10  147 36 54
 8  2   610  304  517  528   273   93   84   78 1880 1111   326  443   13  4382 1349  1370 1663  100 3482  870  962   63   34   14   63 29 43
 8  3  1398  285 1366 1608   857  262  265  224 4872 3604   671  597  113 16409 7687  4733 3989  53010700 5188 1272  104   63   42  198 54  0
 8  4   611  284  238  388   232   71   44   41  825  825     0    0   20  1336 1336     0    0   76  759   25  199   30    1    0   40 49  0
 8  0  3569 2057 3503 3778  1981  667  612  51811041 7921  1456 1664  187 3279815843  8179 8776  130522108 9463 3413  274  127   66  450 49 37

 9  1   225   89  138   75    23   15   19   18  199  182     9    8    9   191  143    39    9   28   93   85    0    0    0    0   19 17 46
 9  2   370  247  265  233   125   26   34   48 1025 1025     0    0   11  1150 1150     0    0   41  692  421  287   45   18    0   47 25 40
 9  3     0    0    0    0     0    0    0    0    0    0     0    0    0     0    0     0    0    0    0    0    0    0    0    0    0  0  0
 9  0   595  336  403  308   148   41   53   66 1224 1207     9    8   20  1341 1293    39    9   69  785  506  287   45   18    0   66 43 26

10 11    17    2    1    0     0    0    0    0    0    0     0    0    0     0    0     0    0    0    0    0    0    0    0    0    0 17 38
10 12    15    5    1    0     0    0    0    0    0    0     0    0    0     0    0     0    0    0    0    0    0    0    0    0    0 28  8
10 13     6    5    0    0     0    0    0    0    0    0     0    0    0     0    0     0    0    0    0    0    0    0    0    0    0  2 52
10 14     7    2    0    0     0    0    0    0    0    0     0    0    0     0    0     0    0    0    0    0    0    0    0    0    0  5 46
10 15    44   21   12    0     0    0    0    0    0    0     0    0    0     0    0     0    0    0    0    0    0    0    0    0    2 47 30
10 20    90   68   34    0     0    0    0    0    0    0     0    0    0     0    0     0    0    0    0    0    0    0    0    0    6 39 39
10 25   227   93  121   55    26    9   12    8  144  144     0    0    1   159  159     0    0    5  124   12    0    0    0    0   10 57 45
10 26   143  240  167  296   147   53   51   47  644  644     0    0   35   220  220     0    0   15  170   43  103   20    0    0   12 19 21
10  0   549  436  336  353   173   62   63   55  788  788     0    0   36   379  379     0    0   20  294   55  103   20    0    0   33 38 40

11  2   632  479  296  496   290   73   81   52  351  351     0    0    4  2194 2194     0    0  110 1778  409  208   28    3    0   52 13 47
11  3   292  183  111  157   109   18   22    8  462  462     0    0    4   581  581     0    0   23  391  179  171   32    0    0   24 45 40
11  4   515  392  454  304   179   40   47   38  632  387   126  119    3  3517 1198   875 1444   68 2309 1172  360   75   10    1   66 11 27
11  5   392  238  309  229   146   31   31   21  607  424    98   85   11  1187  487   399  301   78  922  245  416   57    8    4   40 26  3
11  6   836  561  379  488   301   73   62   52 1475  799   366  310   71  2232  882   729  621  158 1587  508  389   51    4    1   89 44 12
11  0  2667 1853 1549 1674  1025  235  243  171 3527 2423   596  514   93  9711 5342  2003 2366  437 6987 2513 1544  243   25    6  273 22  9

12  1   323    9   87    0     0    0    0    0    0    0     0    0    0     0    0     0    0    0    0    0    0    0    0    0   13 57 44
12  2   931  580 1151 1043   563  160  168  152 2305 1657   287  361   61  9702 4328  2631 2743  252 6875 1798  726   77   18    9   98 38 13
12  3   937  527  768 1020   596  147  168  109 2656 2286   175  195   32  6935 4134  1322 1479  387 4722 2172  764   81   22   13   88 24 49
12  4  1346  808 1778 1475  1084  149  145   97 3116 2078   386  652  131 10844 3475  3215 4154  642 6674 4167 1418  176   53   33  178 40 23
12  0  3542 1924 3784 3538  2243  456  481  358 8077 6021   848 1208  224 2748111937  7168 8376  128118271 8137 2908  334   93   55  371 41  9
```

Course Summary of Learner Control Functions
English 111 at Alexandria
Fall Quarter 1976-77

Figure 7.1

Each entry in the figure corresponds to the number of times students chose a learner control function. For the sixth unit's seventh lesson (UN 6 LS 7) there were 465 MAP requests: the approximately 300 students attending classes for English 111 on the TICCIT system chose the MAP option for segments within Unit 6, Lesson 7 a total of 465 times. The OBJECTIVE displays (OBJ) for the same lesson appeared 212 times, and students sought TICCIT's ADVICE (ADV) 291 times. Counts for RULE (G), EXAMPLE (X), and PRACTICE (Q) appear in sets of five columns. These columns give the total frequency of student use (TOT), frequencies for the EASY (EZ or E), MEDIUM (blank or M), and HARD (HD) difficulty levels as well as the number of requests for HELP (H or HLP). The next two columns (Q+ and Q-) represent the number of practice problems students answered correctly and incorrectly, respectively. The amount of time that students spent on a lesson is given by the last three columns. Unit totals appear as the row labeled Lesson 0.

Although students again chose practice problems more often than any other learner control function, examples of rule applications also contributed to student learning. Especially in those units concerned with organizing essays and writing paragraphs (Units 9 and 10), references to examples nearly equaled or actually exceeded those to practice problems. This perhaps suggests that students chose to learn by example when the generality entailed ambiguity or required practice best done independently of the TICCIT computer system. But the figures for Unit 6 tend to disprove such an interpretation and illustrate the difficulty of attempting to draw inferences from these descriptive data. The sixth unit dealt with spelling, a topic in which examples might be expected to play a significant role given the rote nature of the task and the extent of exceptions to general rules. For the lesson on plural nouns (Unit 6, Lesson 10), student use of EXAMPLE was indeed greater than use of PRACTICE. However, other lessons (e.g., Unit 6, Lesson 7 on word endings such as -tion, -cian, and -sion) and the unit totals (Unit 6, Lesson 0) show a much greater frequency for PRACTICE than EXAMPLE.

Those units to which students devoted the most study time (Units 8 and 12) still show an incidence of practice problems about three times higher than that for examples. These units involved specific rules of grammer for expanding sentences (Unit 8) and analyzing sentences (Unit 12). It would seem that the learning strategies adopted by students very much depended on the nature of the content to be learned. The instructional design of the TICCIT system, while itself independent of subject matter, permitted students to pursue their own preferences for learning.

As with our observations of student-computer interactions in introductory algebra courses earlier in the demonstration, the most popular choice among TICCIT's learner control functions was PRACTICE. Again the use of detailed explanations, available on the TICCIT system through the HELP function, primarily accompanied students' practice in applying rules. The courseware units in which students spent the most time also had the highest counts for the PRACTICE and HELP functions. And these data from an application of the TICCIT program integrated with conventional classroom sessions illustrate the magnitude of the instructional treatment in the evaluation. For just the seven units reported for one course in one academic term (Figure 7.1) there were over 1,500 hours of student contact with the TICCIT system.

Learner Control Functions: Structure. Data on individual students' use of learner control functions were retained in the same format as the course summaries. From these data we wanted to examine the dimensions underlying

TICCIT's instructional design. The mass of data made it prohibitive to study such structure in all courses. A course had to be selected that would be a fair, although perhaps not representative, test case. Low sample size excluded some courses while uneven application of the TICCIT program across classes disqualified others. We chose to combine data from Alexandria's winter and spring quarters and use on-line data from Algebra I in studying interrelationships among TICCIT's functions for learner control.

Of the courseware units required in Algebra I there was evidence suggesting that the unit on linear equations was particularly effective. Student performance on both posttests and topical tests had shown an advantage for the TICCIT program in material on linear equations (see Tables 5.10 and 5.14 in Chapter 5: Student Achievement). Therefore, data from that unit seemed to provide a reasonable basis for exploring the structure of TICCIT's learner control. Counts of each student's use of learner control functions within Unit 20 led to an intercorrelation matrix which indicated the strength of relationship between any two functions. This matrix drew on data from 84 students and included 18 variables, essentially all of those presented in the on-line data summaries except for the totals (GTOT, XTOT, and QTOT) which were redundant.

A factor analysis according to principal components resulted in a description of the function intercorrelation matrix in terms of three factors. The latent roots for these factors each exceeded an eigenvalue of 1.00 (8.22, 2.60, and 1.90) while no other factor had a root as high. Three factors were rotated by a varimax orthogonal procedure. The varimax solution gave the factor loadings shown in Table 7.6 and accounted for 71% of the total variance. Generally the learner control functions had a high loading under just one factor and low loadings under the other two factors: the factor structure was relatively simple and clean.

Learner Control Functions: Rotated Factor Matrix
(after varimax orthogonal rotation)

Unit 20 Linear Equations

	Factor Loadings			N = 84	
Function	I	II	III	Mean	sd
MAP	.73	.10	.16	45.89	32.60
OBJECTIVE	.67	.46	.01	35.48	35.32
ADVICE	.68	.04	.12	49.10	60.40
RULE-MEDIUM	.66	.15	.42	24.75	19.41
RULE-HELP	.21	.05	.88	7.07	8.77
RULE-EASY	.19	.05	.91	7.36	8.95
RULE-HARD	-.04	.28	.76	3.48	6.47
EXAMPLE-EASY	.31	.79	-.02	64.89	88.02
EXAMPLE-MEDIUM	.15	.80	.02	5.18	10.42
EXAMPLE-HARD	-.03	.75	.28	5.27	10.58
EXAMPLE-HELP	.18	.78	.18	11.24	18.71
PRACTICE-EASY	.90	.09	-.00	170.77	141.43
PRACTICE-MEDIUM	.87	.16	.18	42.05	33.51
PRACTICE-HARD	.91	.12	.08	37.63	31.30
PRACTICE-HELP	.78	.15	-.01	60.35	72.66
PRACTICE (correct)	.88	.04	.06	149.70	120.90
PRACTICE (incorrect)	.88	.17	.00	76.88	65.53
TIME	.67	.35	.22	11.26	7.76

Table 7.6

As might be expected, the factors themselves correspond closely to features of TICCIT's instructional design.

The three factors given in Table 7.6 lend substantive support to the conceptual design of the TICCIT system. Those counts related to student use of the PRACTICE function dominate the first factor. Thus, Factor I might be termed a practice dimension. Consistent with other data on student interaction with the TICCIT system, this factor has the most descriptive power. Most functions load highly under Factor I, and it alone accounts for 40% of the variance in student use of learner control options. Factor II clearly concerns the use of example. It represents the Example dimension of TICCIT's design. The highest loadings under Factor III, the Rule dimension, pertain to student use of the RULE feature. However, the version of the generality most often seen by students, RULE-MEDIUM, appears to belong under Factor I, Practice.

It does seem that student interaction with the TICCIT system was largely a matter of work on practice problems. Under one factor best described as Practice come various combinations of the practice feature (e.g., PRACTICE-HARD, PRACTICE-HELP) as well as functions related to the structure and management of instruction (i.e., MAP and ADVICE). Further, the most frequently displayed version of the rule statement and the amount of time spent on the computer system reach their highest loadings under Practice, although both predictably show some complexity in the factor structure by their moderate loadings under other factors. Perhaps these split loadings serve as a reminder that each dimension, Practice, Example, and Rule, explained a substantial amount of variance in student use of learner control functions. And there was certainly variation among students judging from the magnitude of the standard deviations for the functions. Distributions of counts for student use of learner control were skewed in the positive direction.

The size of the standard deviations given in Table 7.6 and the course summary shown earlier in Figure 7.1 suggest the need to replicate these results before accepting them as definitive for the structure underlying the instructional design of the TICCIT system. The standard deviations indicate the very real possibility of unreliable data. Some counts of individual students' use of learner control functions seemed extraordinarily high, yet there was no convenient mechanism for verifying them. Summary counts taken at the course level gave evidence of use of learner control functions dependent on courseware units and even lessons. Factor analysis of other units may yield different results. But the consistency of the structure found in our analysis with the description of student-computer interactions obtained through observations may instead point to the applicability of Practice, Example, and Rule as dimensions for learner control in math courses. At least these dimensions lead us away from difficulty levels (i.e., EASY, MEDIUM, HARD), system explanations (i.e., HELP, ADVICE), and mode of presentation (i.e., didactic RULE and EXAMPLE versus interactive PRACTICE) as dominant facets of TICCIT's instructional design.

Progress Reports. Each week instructors received a report generated by the TICCIT computer system giving the course status of students enrolled for TICCIT classes. Figure 7.2 gives an example of such a report from Beginning Algebra at Phoenix. This particular report was the last one produced for the spring semester of 1976, and thus it reflects students' status at the end of an academic term. It hardly presents a representative picture of student progress since fewer students completed their studies in this class than in other TICCIT classes. But it does illustrate the kind of information regularly available to teachers, the range of student progress under a self-paced system, and the variation in the amount of time students spent on the TICCIT system.

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PHOENIX COLLEGE TICCIT WEEKLY REPORT           SORTED BY NAME

COURSE/SECTION NUMBER: 007/XX                             DATE:  05/29/76

LP=NUMBER OF LESSONS PASSED
SW=START WEEK
TOL=TIME ON LINE
LD=LAST DAY OF SYSTEM
T/L=TRIES PER LESSON
0=NO TEST REQUIRED FOR THIS LESSON
1=PASSED ONE TEST THE FIRST TIME
2=PASSED THE TEST THE SECOND TIME
3=PASSED THE TEST THE THIRD TIME
Y=LESSON BOX IS YELLOW
R=LESSON BOX IS RED
.=NEVER IN THIS LESSON

              UNIT:  24  23 22 21  20   17
            LESSON:  000 00 00 000 0000 0000
STUDENT #            321 21 21 321 4321 4321 LP SW TOL    LD    T/L

000000001            ... 31 13 113 133R .... 10 13 041:22 05/05 2.0
000000002            ... R. .. ... .... ....  0 17 000:27 02/06 0.0
000000003*           000 12 11 11Y 1313 111Y 13 13 012:14 04/20 1.3
000000004*           000 11 13 211 1121 2Y.. 12 13 013:07 02/09 1.4
000000005*           000 13 12 113 11R. R...  9 13 004:50 02/26 1.5
000000006            ... .. .. ... .... ....  0 15 000:00 00/00 0.0
000000007            ... Y. .. ... .... ....  0 13 000:00 00/00 0.0
000000008            ... 11 .. ... .... ....  2 13 005:44 03/10 1.0
000000009            ... .. .. ... .... ....  0 13 000:18 01/19 0.0
000000010            ... 11 11 111 11Y. ....  9 13 008:20 04/01 1.0
000000011            ... Y. .. ... .... ....  0 13 000:22 01/19 0.0
000000012            ... 1Y .. ... .... ....  1 13 001:10 01/19 1.0
000000013*           000 11 13 111 1233 1311 15 13 054:26 05/05 1.6
000000014            ... .. .. ... .... ....  0 13 000:00 00/00 0.0
000000015            ... 13 23 R.. .... ....  4 13 063:04 05/05 2.2
000000016            ... 2. .. ... .... ....  1 13 000:26 01/20 2.0
000000017            ... 13 3Y ... .... ....  3 13 031:41 05/05 2.3
000000018            ... 12 Y. ... .... ....  2 13 001:09 02/11 1.5
000000019            ... Y. .. ... .... ....  0 13 001:32 01/20 0.0

TOTAL TOL:  240:12        SOME AVERAGES    TOL:  12:39      LP:  4     T/L:  1.6
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*Reenrolled for this course after receiving a non-credit grade in the previous semester.

Student Progress Report

Figure 7.2

Students had to complete five units (Units 23, 22, 21, 20 and 17) in order to receive credit for Beginning Algebra. These units included 15 lessons and over 80 segments. So students had to maintain a schedule equivalent to one lesson per week or slightly better than one segment per day of classes throughout the semester. The basic instructions distributed to students at the start of an academic term made this point clearly. Yet students typically failed to pace themselves or encountered severe trouble in learning. For example, the student listed tenth in Figure 7.1 had passed every test on her first attempt and had done so in a minimal amount of time. Certainly she was capable of completing the course, but stopped attending classes with over a month still left in the semester. In contrast to this case, the fifteenth student attended classes regularly and spent over 60 hours on the system. And he passed only four lessons. Even students who had reenrolled for the course and stood close to completion (e.g., the third, fourth and fifth cases in Figure 7.2) neglected their studies toward the end of the term. Other students simply never attended a class or made only a minimal effort. This lack of persistence among capable students and painstaking progress among students weaker in subject matter familiarity contributed to the low completion rates found in math courses under the TICCIT program.

Part of the explanation for student progress, such as that depicted in Figure 7.2, might rest with the lesson tests embedded in the TICCIT courseware. These tests were designed to assess student mastery and a student had to pass each test within three attempts in order to proceed with his students. To be sure that students passed, all third attempts required personal supervision by an instructor. Half of the lessons passed in our admittedly extreme example took more than one attempt at their respective mastery tests, and approximately one-third of the successful attempts were third attempts guaranteed to succeed by the direct individual intervention of an instructor. This failure and repetition of mastery tests was not unique to math courses. It happened in English courses as well (as illustrated in the history of test attempts for Units 8 and 12 in English 111, see Figure 7.1).

Rather than facilitate student progress, the mastery tests on the TICCIT system seemed to pose an obstacle. A test question taken from an original version of the math courseware called for the lowest common multiple of 1,568 and 735. That question occurred in the first lesson test encountered by students in introductory algebra. It was deleted in the courseware revision process prior to the demonstration, but it still serves as an illustration of a weak link in the curriculum. The task of test construction was left to members of the production team inexperienced with such work, and there was scant opportunity for the developers to conduct a formative evaluation of test content and mastery levels. Especially in the early phases of the TICCIT project, mastery testing impeded student progress. It would be our contention that further revision of tests should improve completion rates. Of course, we as evaluators may be prone to see such deficiencies and be overly sensitive to them, and thus find ourselves returning to stress the difficulty of drawing inferences from descriptive data lest this comment be taken as conclusive.

7.2.c Time and Learning

The relationship between time and learning (see Bloom, 1974) was a secondary issue in this evaluation. Like other aspects of student interaction with the TICCIT system, there were no grounds for comparison between student groups exposed to the TICCIT program and others taught by conventional methods. Yet the nature of the TICCIT program gave us an unusual opportunity to collect data on the amount of time students spent in learning. Measures of that learning were already a part of the evaluation. And the resulting evidence, however imperfect and tentative, warrants presentation here. Contrary to popular expectations we found no strong relationship between time spent in learning and external measures of student achievement.

Time Spent on the TICCIT System. Course averages for the amount of time that students spent on the TICCIT system appear in Table 7.7. Calculated for all students who attended classes, the highest mean occurred in English 111. Students in a course which combined the TICCIT program with traditional classroom practices spent more time on the computer system than students in courses representing mainline applications of the TICCIT program. It is true that this course met five times per week while other courses carried three credits. But the shorter academic term of a quarter probably compensates for this difference. The real reason for the higher means in both English 111 and English 19 during the fall academic term might be the extent of instructor supervision. By then instructors were familiar with the TICCIT English curriculum, and these courses particularly represented a mixture of classroom meetings or small group discussions with sessions on the TICCIT system. With regular instructor contacts outside of TICCIT sessions students perhaps felt responsible for their own learning and answerable to a specific faculty member.

There was substantial variation among students in the amount of time spent on the TICCIT system. Some students spent virtually no time working on the TICCIT system while others devoted a considerable number of hours (see, for example, Figure 7.2). Those students who took posttests did, on the average, spend more time than all students enrolled in a class regardless of their attendance or course progress. Indeed the means for students with posttests indicate attendance

Time Spent on the TICCIT System: Student Contact Hours
Descriptive Statistics for Selected Courses
Calendar Year 1976

		All Students			Students with Posttest			Correlations		
Course	Term	N	Mean	sd	N	Mean	sd	Pretest	Posttest	Lessons Passed
Math 007	Spring Semester	159	21.02	20.7	39	38.64	26.4	.00	-.14	.52
Math 31	Winter Quarter	98	26.88	22.5	54	35.93	25.1	-.02	.30	.62
Math 31	Spring Quarter	53	23.94	17.4	27	34.15	17.5	.06	.06	.38
English 19	Spring Semester	72	20.42	16.3	20	30.55	19.1	.22(-.05)*	-.18(.14)*	.60
English 29	Spring Semester	60	22.08	21.0	28	35.14	21.7	.15(.21)	.24(-.10)	.75
English 19	Fall Semester	166	29.64	16.1	82	38.94	11.8	-.08(-.09)	-.29(-.30)	.73
English 29	Fall Semester	108	24.16	15.4	40	33.67	10.8	-.23(-.21)	-.40(-.34)	.72
English 111	Fall Quarter	105	30.13	23.3	66	37.14	22.8	-.09(-.14)	-.33(-.15)	.79

*The correlations within parentheses refer to the relationship between time and essay tests while those without parentheses refer to time and objective tests.

Table 7.7

equivalent to three and sometimes over four class periods per week. That the standard deviations for these cases remain large might be taken as a sign that the time spent was related to entrance ability or contributed to posttest performance. Either interpretation would be incorrect.

Time and Test Performance. It might be suggested that students weaker in terms of their entrance ability would need to spend more time on the TICCIT system in order to attain mastery. Thus there should be a negative correlation between time on-line and pretest scores. Or the position adopted might be that students of comparable entrance ability would differ in their posttest performance as a direct function of the amount of time they had spent on the TICCIT system. There should then be a positive correlation between time on-line and posttest scores or a positive partial correlation between these two variables adjusted for pretest scores. The correlations given in Table 7.7 support neither position. And regressions similar to those reported for student achievement (see Tables 5.5, 5.6, 5.12 and 5.13 in Chapter 5: Student Achievement) but conducted just for students within the TICCIT condition, failed to show one instance in which time on-line contributed to the explanation of variance in posttest performance.

Since the notion that time and learning should be related in a mastery system has such great intuitive appeal, finding no appreciable relationships between time on-line and test performance came as a surprise to us. But the finding is less puzzling in the context of other results. There was evidence of an achievement-treatment interaction both in the selective nature of the TICCIT program with regard to completion rates in math courses and in the role played by interaction terms in the analyses for completion and achievement in English courses (see Chapter 4: Course Completion Rates and Chapter 5: Student

Achievement). This perhaps suggests that the TICCIT program provided insufficient instructional support for students weak in entrance ability.

We should expect to find a relationship between time and learning only under conditions in which the instructional treatment changes as a function of time. Simply proceeding at a slower pace repeating the same instructional sequence would not be likely to benefit students incapable of understanding the material upon first exposure. The nature of the treatment must also change. Yet the very students who might otherwise derive the most benefit from additional time on the TICCIT system probably lacked the sophistication to manipulate the system through learner control so as to meet their own needs, assuming that such manipulation was possible. Indeed, aggregating our observations of students at TICCIT terminals either by cycles within a term or by matches for a student across cycles had not shown any consistent pattern of differences in students' learning strategies.

Yet the data on time and learning were equivocal. Taking a measure of student learning from system records we found a consistent positive relationship between time on-line and lessons passed (see Table 7.7). The amount of time students spent on the TICCIT system contributed significantly to the explanation of variance in the number of TICCIT lessons students had passed. This held for all the courses listed in Table 7.7 in analyses which also included pretest as an explanatory variable. It would be tempting to discount such results as inherent to the use of an achievement measure taken from the TICCIT system. But the analyses with this internal measure of achievement included substantially larger data sets than those with our external measure of achievement, the posttest. For example, there were 106 students in Math 007 for the spring semester with data on lessons passed, time on-line and pretest but only 32 with posttest, time on-line and pretest. Whether there was a relationship between time and learning depends on which measure of achievement we choose to accept.

Chapter 8

Faculty Acceptance and Teacher Role

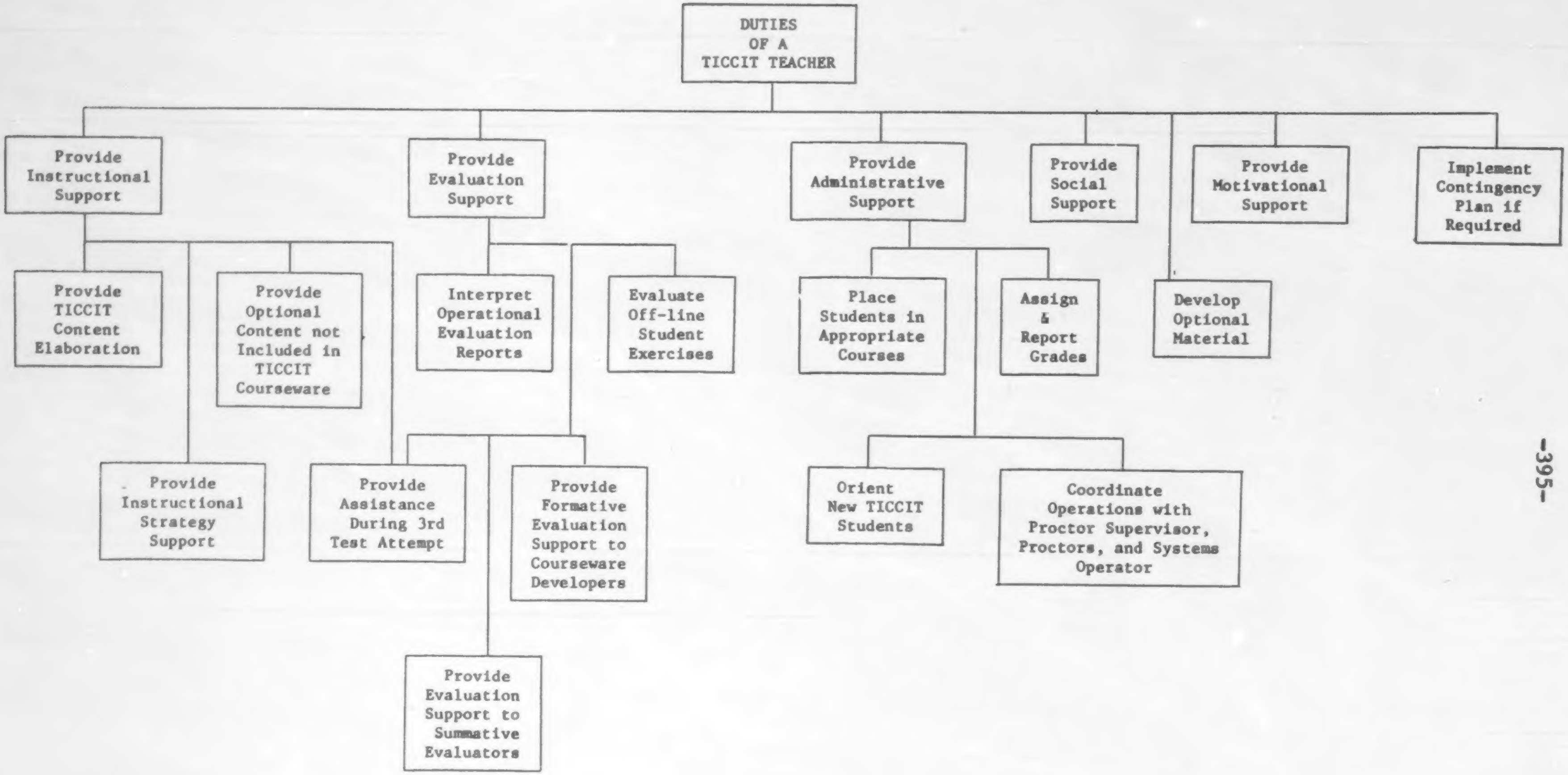
Thus far, this report has focused on evaluating the impact of the TICCIT program in terms of its effects on student performance. The present chapter focuses on the program in relation to the teacher. Specifically, this chapter addresses the issues of the teacher's role under the TICCIT program and faculty acceptance of the program. Describing what teachers did in classes offered on the TICCIT system is pertinent for both understanding the context of the program's impact on student performance and appreciating the nature of the program's demands upon teachers. Documenting faculty beliefs about educational practices and computer-assisted instruction and later their reactions to the TICCIT program gives us the benefit of the colleges' initial views on the project and its premises, and of the colleges' subsequent opinions based on experience with the program.

Two major sections appear in this chapter. The first section presents questionnaire and observation data relevant to faculty activities. Instructors of target courses in English and mathematics estimated what percentage of their time had been devoted to various tasks, such as preparing for class and counseling students on questions about course content. Also, the tasks performed by instructors in TICCIT classes were recorded through direct observations. The second section describes faculty attitudes prior to the installation of TICCIT systems at the colleges and documents their reactions to the program after nearly two years of experience with it. These descriptions of faculty opinions and judgments come from the results of surveys conducted at two different points in the project's history. This chapter, like the previous one on student activities, was meant to be descriptive and includes no formal estimates of treatment effects. Instead it provides a rather comprehensive picture of the TICCIT program in terms of faculty duties and attitudes.

8.1 Teacher Role

There has been considerable speculation about what the role of the teacher would be when technology became commonplace in our schools. Often it is said that technology will relieve teachers of routine duties and thus make better and fuller use of their capabilities. This interpretation of technology's impact on teachers might be restated in a simple, direct manner: "They will be freed to do the things they have long wanted to do but never had the time" (Gillett, 1973, pp. 82-83). Other projections involve radical changes in teachers' responsibilities. For example, one report forecasted a shift in the teacher's role from surveyor of information to master of the resources of learning (Kerr, 1972). The view of technology held by Norris (1977) incorporates the themes of both relief and change. He foresaw technology, more specifically computer-based education, giving teachers more time to work with individual students and creating demands for new curricular materials produced by teachers.

Its developers had anticipated that the TICCIT program would change the nature of a teacher's duties and responsibilities. They had addressed this issue in the early stages of project planning (e.g., Black, 1974; Bunderson, 1973). But it was quite difficult to define the teacher's role without the benefit of some experience in teaching by mainline computer-assisted instruction. The developers instead offered a broad portrayal of possible duties, as shown in Figure 8.1. Actually these projected duties


DUTIES OF A TICCIT TEACHER
Provide Instructional Support
Provide Evaluation Support
Provide Administrative Support
Provide Social Support
Provide Motivational Support
Implement Contingency Plan if Required
Provide TICCIT Content Elaboration
Provide Optional Content not Included in TICCIT Courseware
Interpret Operational Evaluation Reports
Evaluate Off-line Student Exercises
Place Students in Appropriate Courses
Assign & Report Grades
Develop Optional Material
Provide Instructional Strategy Support
Provide Assistance During 3rd Test Attempt
Provide Formative Evaluation Support to Courseware Developers
Orient New TICCIT Students
Coordinate Operations with Proctor Supervisor, Proctors, and Systems Operator
Provide Evaluation Support to Summative Evaluators

Duties of a TICCIT Teacher

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*Taken from TICCIT Community College Implementation Plan (2nd ed.), 1974, Appendix I, page 34.

Figure 8.1*

correspond fairly closely to duties associated with conventional teaching methods. Elaborating on the content of TICCIT courseware, for example, might be likened to elaborating on a textbook's coverage of a topic. Assisting students on a third attempt of a mastery test would perhaps parallel counseling students on especially poor test performance. Despite such similiarities there should be marked differences in the relative demands of teacher tasks if the TICCIT program succeeded in supplanting some routine instructional responsibilities.

The approach followed here in documenting the teacher's role involves comparisons across conditions as well as records of activities from just TICCIT classes. We can begin to define what a teacher does under the TICCIT program by noting points of similarity and contrast with those activities normally associated with teaching. A questionnaire on faculty activities (see Appendix J) provided a data base sufficient for this purpose. Still, faculty estimates of the proportion of their time spent in various activities may be just rough figures and convey only a sense of teacher role. A more complete description of teacher activities can come from direct observations. Within TICCIT classes we observed the tasks performed by instructors while students worked at the computer terminals. The description of teacher's role that emerged from these observations supplements the results of the self-report questionnaire in that it gives an independent, objective account of what teachers did under the TICCIT program.

8.1.a Instructor Activities across Conditions

The activity questionnaire made it possible for us to contrast the duties fulfilled by teachers conducting TICCIT classes with those associated with teaching the same course in a conventional manner. Faculty responses to the questionnaire simply reflected their own estimates of how they had spent their time. Decisions regarding what pattern of time allocations might best be suited to mainline computer-assisted instruction were usually made by an individual faculty member in accordance with the demands of the situation. And the situation was, to a large extent, a function of departmental policy on student-teacher ratio, course requirements, and assigned classroom/computer hours. The same combination of individual autonomy and departmental policy can be said to affect instructor activities in courses taught by familiar lecture-discussion practices. Just as it would be speculative to attribute any of the effects of the TICCIT program to a particular component of the system, it would likewise be inappropriate to consider any change in instructor activities as an effect of the TICCIT program rather than as a consequence of faculty decisions or departmental policy.

These data on teacher role represent what happened at the community colleges involved in the TICCIT demonstration. They do not necessarily represent the role model advocated by the developers or the procedures that other colleges should try to follow. Instead, the data from the instructor activity questionnaire should help in understanding the context within which the TICCIT program had significant impact on student performance.

Activity Questionnaire. The questionnaire designed for collecting data on instructor activities had essentially two parts, one specific to course sections and another on general types of activities perhaps unrelated to a particular course (see Appendix J). The first part specific to course sections dealt with instructors; use of classroom hours and the proportion of their time given to various tasks. The second, general part concerned the amount of time faculty spent on college committees, student organizations, further education in their subject field, informal discussions with students and colleagues, and similar duties involved in teaching. This second part was included in the questionnaire in order to check on instructors' use of somewhat discretionary time, since the TICCIT program might 'free' instructors to engage in activities aside from those tied to specific course sections.

Sample. Faculty members who taught sections of target courses received the instructor activity questionnaire at the end of the academic terms of the 1975-76 school year. This was very much a fixed sample of respondents: there were less than 10 faculty members in each college's math department and fewer than 20 instructors in each English department. And not all of these faculty members taught sections of courses designated for evaluation. The sample of English instructors was further limited by the fact that the demonstration period for TICCIT courseware for English began in the second half of the 1975-76 school year. Still, instructors completed and returned 40 questionnaires. Of these, 28 forms were from math instructors and 12 from English instructors; one-fourth of the respondents were part-time instructors. It might also be noted that these questionnaires were collected after the developers of the TICCIT program had given orientation sessions to train faculty in the use of the TICCIT system. Still, faculty responses often represented what had happened in their first practical exposure to teaching with the TICCIT system.

Questionnaire Data: Activities specific to Course Sections. A summary of the time allocations for tasks specific to course sections appears in Table 8.1. This summary covers instructor activities in math courses by college since instructors at Phoenix taught an assigned number of hours on the TICCIT system and instructors at Alexandria taught specific TICCIT sections of math courses. The descriptive statistics on instructor activities in English courses, however, appear for both colleges taken together. Twelve responses from one academic term of the demonstration period for English courses did not warrant a delineation by college. The modes of instruction and the types of activities listed in the table correspond to those given in the questionnaire.

Clearly the treatment was implemented. Math instructors spent over five classroom hours per week with the TICCIT system, and English instructors had the equivalent of three class sessions per week on the TICCIT system. By contrast, instructors devoted their classroom hours to lecture and discussion in course sections taught in a conventional manner. From the total number of classroom hours it can be seen that the math department at Phoenix considered two sessions on the TICCIT system to be the same as one regular classroom session. This policy was adopted in order to compensate for the homework assignments done for lecture-discussion sections. At Alexandria the total number of classroom hours for math courses indicates

Instructor Activities Survey
Item Responses across Instructional Conditions: Activities specific to Class Sections
Academic Year 1975-76

	Math Courses Phoenix				Math Courses Alexandria				English Courses Alexandria and Phoenix			
	TICCIT (N = 5)		Lecture (N = 18)		TICCIT (N = 14)		Lecture (N = 7)		TICCIT (N = 5)		Lecture (N = 7)	
Item Stems	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd
Number of classroom hours (per week) spent on:												
(a) Lecture	0	0	1.61	.99	0	0	2.21	.27	.10	.22	1.36	1.18
(b) Discussion	0	0	1.21	.62	0	0	1.86	.38	.40	.65	1.07	.45
(c) Tests, Quizzes	0	0	.40	.12	0	0	.64	.38	0	0	.38	.49
(d) TICCIT	5.20	1.10	0	0	5.28	2.02	0	0	2.50	.71	0	0
(e) Other	2.00	4.47	0	0	.32	.87	0	0	0	0	.43	.53
Percentage of time (per week) spent on:												
(a) Planning for class	0	0	1.11	2.74	6.21	16.00	1.57	4.16	7.00	8.37	3.57	7.48
(b) Conducting class	16.25	21.36	51.67	20.72	27.93	33.69	46.14	6.26	48.60	29.83	26.71	16.43
(c) Preparing lectures, discussions	0	0	15.22	8.90	0	0	13.86	4.38	4.00	8.94	15.43	7.79
(d) Developing student assignments, tests	0	0	7.11	2.78	0	0	10.14	.38	0	0	10.00	2.89
(e) Correcting student assignments, tests	18.75	17.50	11.22	5.93	2.36	3.84	11.57	3.74	13.40	11.52	21.43	18.42
(f) Advising individual students on their course progress	6.25	4.79	2.22	2.18	12.00	9.62	3.00	2.52	6.40	4.98	9.57	11.46
(g) Counseling students on content questions	34.50	25.58	5.50	5.34	40.93	31.27	6.71	3.45	11.00	21.91	7.86	12.20
(h) Counseling students on matters not specifically related to this course	6.25	2.50	1.25	1.72	4.07	3.83	.86	1.07	3.60	2.19	2.00	3.65
(i) Administrative duties	4.25	1.50	3.03	2.02	3.57	3.00	4.71	3.15	4.20	6.38	3.43	3.31
(j) Other	13.75	24.28	1.67	7.07	3.00	5.32	1.43	3.78	2.00	4.47	0	0

Table 8.1

that the math courses there were five-credit courses which met five times per week. These figures on the use of classroom hours also make it apparent that instructors of TICCIT sections of English courses supplemented the computer-based curriculum with their own discussions and sometimes a lecture.

The data on the percentages of an instructor's time spent on various tasks (Table 8.1) reveal a quite different pattern of activities across conditions. In math courses instructors with lecture sections usually spent two-thirds of their time in conducting class, preparing lectures, and developing student assignments and tests. The TICCIT program cut this preparatory and didactic work down to one-fourth or less of an instructor's role. Instructors with TICCIT classes instead devoted much of their time to counseling students on content questions. At least in this sense the TICCIT program did free instructors to work with individual students.

That instructors of math courses on the TICCIT system spent a considerable portion of their time on individual students' content questions perhaps supports other findings. It may signify the difficulty encountered by students in understanding mathematical concepts as presented in the TICCIT program and, therefore, the lower course completion rates in TICCIT math courses. It may also indicate the assistance which enabled other students not only to complete a math course on the TICCIT system but to gain higher scores on achievement posttests as well.

The pattern of activities reported by English instructors with TICCIT classes seems to resemble the estimates given by math instructors with lecture sections (see Table 8.1). Nearly one-half of their time was devoted to conducting classes and one-tenth to correcting student assignments. English instructors with lecture-discussion classes, by contrast, spent just one-fourth of their time conducting classes, but developing classroom presentations and student assignments took another fourth of their time. Again the TICCIT program seems to have lightened the burden of preparatory work.

Before considering faculty responses to questions about their general activities it may be useful to note the tentative nature of the data presented in Table 8.1. Both the numbers of cases on which these data rest and the size of the standard deviations in relation to the means would be arguments against drawing firm conclusions from these descriptive figures. For example, it might appear as if math instructors at Phoenix had their TICCIT classes spend two hours per week in some "other" mode of instruction. But the large standard deviation (4.47) hardly suggests consensus among the five respondents. A single instructor had estimated that he spent ten hours per week on courseware revisions, and this one response led to the unrepresentative average given in the table. We reiterate, then, that these data and those which follow in this section should be viewed as descriptive.

Questionnaire Data: General Activities. Instructors' estimates of the hours per week spent on general activities cannot be attributed to the TICCIT program as readily as their estimates of section specific tasks. Each full-time faculty member taught several classes, and this teaching load served to obscure the impact of a single TICCIT class on general activities such as college committees, student organizations, informal discussions with colleagues and students, and curriculum revision. Yet instructors with TICCIT classes reported spending substantially more time on informal discussions, activities to enhance their own knowledge, curriculum revision or course procedures, and the TICCIT project. For each of these general activities faculty with TICCIT classes estimated devoting four or five hours per week while faculty with lecture-discussion sections spent just one or two hours per week.

This higher level of general activities among teachers with TICCIT classes might be due to the release from course preparation afforded by the TICCIT program. The hours given to activities beyond a specific course section may be, in effect, the counterpart of the usual preparation time. This would be consistent with the view that computer-assisted instruction frees teachers to engage in other activities. It seems probable, however, that there is another explanation for the increase in instructor's extra-curricular activity. An innovative project with active faculty participation could easily lead to greater time commitments by teachers. Without data on the total amount of time spent on all teaching duties and activities, we find it premature to choose between these two interpretations.

8.1.b Teacher Tasks under the TICCIT Program

An accurate account of teacher tasks under the TICCIT program required conducting a series of observations as part of the evaluation. These observations took place at the demonstration site where the evaluator had placed a field representative with prior experience in observations as a mode of data collection. The description of teacher tasks possible from direct observations of instructors in TICCIT classes obviously relied less on retrospective estimates of the time spent in various activities. It instead emerged from close and regular contact with instructors at work under the TICCIT program. Nevertheless, this picture of teacher tasks is descriptive only and does not represent a prescription for other situations or an inference about TICCIT effects under different conditions. It does perhaps contribute to a fuller appreciation of the conditions under which we conducted this evaluation.

Observation Record. After attempting to record the activities of all staff and students present in a TICCIT classroom, the observer began to focus on the instructor and one proctor. Also revised was the coding scheme with pre-specified categories. Instead the observer simply noted the activity in which the instructor or proctor was engaged and maintained a record of the amount of time spent on that activity within a class period. This approach proved to be both more efficient for data collection and better descriptive of instructor tasks than a rigid form for observations.

Schedule and Sample. During the spring and fall semesters of the 1976 calendar year, our field representative conducted observations of math and English classes on the TICCIT system. Each observation lasted one class session. In the spring semester, the TICCIT math classes at Phoenix met daily from 7:30 am to 3:30 pm as well as two evenings per week. Since instructors were assigned to cover hours of system operation rather than specific course sections, classes included students enrolled for introductory algebra as well as students enrolled for college algebra. Classes convened in a large room reserved for the TICCIT program; the room had 75 carrels with TICCIT terminals. On 36 occasions the percentage of time instructors spent on various activities was recorded. The observer also monitored proctor activities in 33 of these observations.

Unlike the TICCIT math classes, the English courses offered on the TICCIT system at Phoenix followed much the same schedule as lecture-discussion classes. Students chose a particular course section that had a definite class schedule (three class periods per week) as well as a specific instructor. Each section held students enrolled for the same course, and students always met with the same instructors. This contrasts sharply with the procedures in math whereby students registered for hours on the TICCIT system rather than for a section of a particular course or classes with a specific instructor. However, English instructors conducted their classes free from any formal departmental consensus on teaching with the TICCIT program and so structured their classes in various ways, whereas math faculty had agreed on a set of procedures and standards for all TICCIT math classes. Six TICCIT sections, taught by four instructors, of a course in basic English were observed in the fall semester. Of these sections, two classes met regularly in the same large TICCIT classroom where math classes met, and the other four classes met in a smaller room with about 40 carrels and TICCIT terminals. The observer recorded instructor and proctor activities for each section on six different occasions, once every two weeks, for a total of 36 observations in TICCIT English classes.

Context for Teacher Role. Seven members of the math faculty took assignments to supervise the TICCIT classroom. These instructors shared responsibility for all students enrolled for math courses on the TICCIT system; one instructor was present for every scheduled hour of system operation. In addition, two to six proctors were present for TICCIT classes. The proctors were students with a knowledge of basic math hired on a part-time basis. Nearly 20 proctors covered the classroom hours scheduled for TICCIT math courses. Typically, one instructor and three proctors were available to assist students working on the computer system.

Class rosters from the beginning of the semester showed an average of 41 students registered for each TICCIT math class offered in regular daytime hours. Counts taken during observations, however, revealed an average class attendance of 30 students. By mid-semester 24% of the TICCIT math students either had themselves withdrawn from math courses or had been withdrawn by instructors due to their poor attendance. Indeed, the irregular attendance patterns depicted in Figure 8.2 probably contributed to the failure of some students to complete math courses on the TICCIT system (see Chapter 4: Course Completion Rates). The tabled attendance data also verify the fact that most students made a conscious effort to finish their math course on the TICCIT system, as suggested by the number of hours students spent on the system (see Chapter 7: Student Activities). These attendance figures represent the average number of students present in TICCIT math classes during five cycles of observations. Instructors activities did tend to vary somewhat with the number of students present.

Sections of English courses on the TICCIT system had the same instructor for all class sessions. Each section followed the procedures established by its instructor. Two instructors assigned themes in addition to the writing requirements already included in the TICCIT courseware (units 10 and 11). One of these two instructors also divided her students into four small groups; each group met with her in a supplementary conference room once a week for one-half hour. In these small group sessions away from the

Attendance in TICCIT Math Classes

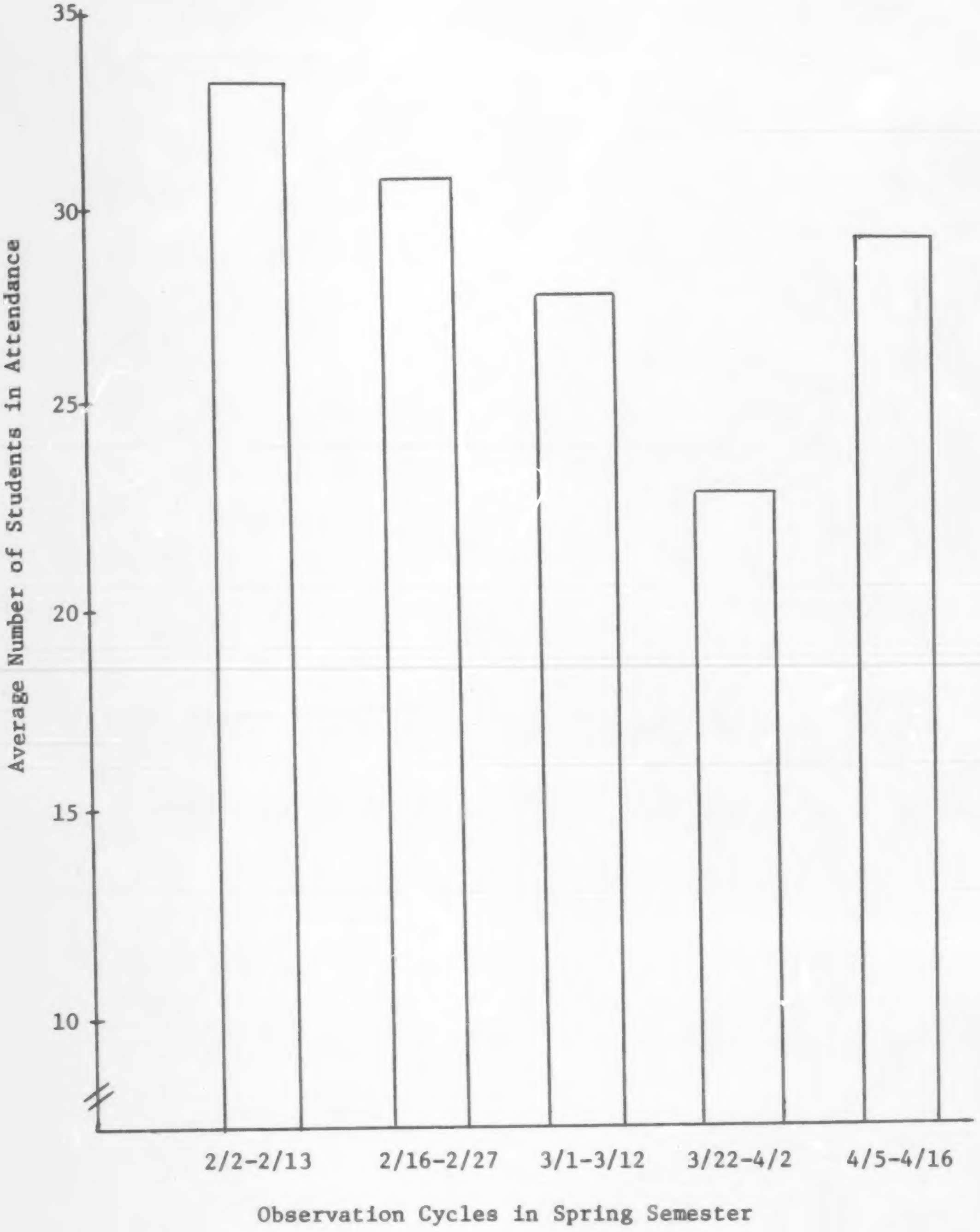

Figure 8.2

TICCIT system, students discussed themes written at home. A substitute took the instructor's place in the TICCIT classroom during these conferences. The other instructor who assigned themes gave students class time to write their assignments and discussed the themes with each student individually during class time. A third instructor also met with students in the conference room, but on an individual basis and primarily about the writing assignments from the TICCIT units. All three of these instructors followed the sequence of the TICCIT units as given in the courseware map structure (see Chapter 1: Introduction). The fourth instructor with TICCIT English classes in the fall semester altered the suggested course sequence so that students worked on spelling and parts of speech before sentence structure. These changes departed from the sequence built into the TICCIT program, and the instructor had to meet regularly with individual students in order to keep abreast of their course progress and advise them of what work should be undertaken next.

Each class period of a TICCIT English section also had proctors and, naturally, students. The number of proctors present for a class session ranged from one to four, with an average of two proctors available for a given class. The number of students in attendance for a basic English course ranged from 10 to 30. The largest course section usually had 25 students, and the smallest of the six sections ordinarily had 13 students in attendance. This information about the persons present in TICCIT classes and course structure perhaps begins to convey the conditions under which we observed the tasks performed by instructors.

Tasks of TICCIT Teachers. Responding to student questions about content and monitoring student performance on mastery tests occupied the bulk of instructors' class time. Math instructors spent nearly two-thirds of their time engaged in these two tasks, and English instructors devoted over two-fifths of their time to the same tasks. Moreover, the five tasks which occupied nearly all of the instructor time in math classes also consumed most of instructors' time in English classes. In order of the percentage of time devoted to each task, the five activities most often performed by TICCIT teachers were: answering student questions on content; monitoring mastery tests; circulating among students so as to be alert to possible questions or problems; performing managerial work; and holding discussions with other staff, visitors, instructors, or the observer.

Proctors held less authority and responsibility in TICCIT classes and served primarily as technicians familiar with the mechanical aspects of the TICCIT system and procedures for its use. Proctors' time allocations reflected their limited role: they spent most of their time to administering off-line tests on spelling. These proctor functions may be very much a function of the college's definition of staff duties. At Alexandria the two proctors assumed greater responsibility for suggesting possible learning strategies and for advising students on content questions. But one of these two proctors had taught mathematics at the secondary school level and the other was a graduate student in educational technology at a nearby university. The data from the observations at Phoenix represent the tasks performed by proctors and instructors at that demonstration site.

Table 8.2 presents a summary of the percentage of time which instructors and proctors had allocated to various tasks. It had not been the intent of the developers of the TICCIT program that instructors spend as much as 65% of their time in answering students' questions on content and monitoring test attempts. The TICCIT program was to be self-sufficient and self-explanatory: students would learn on the system and most students would pass mastery tests on their first attempt. Actually, students often sought the help of an instructor and frequently required assistance in their third and final attempt at a mastery test (see Chapter 7: Student Activities). Instructors responded to student needs when they provided further explanations of concepts or instances presented in the TICCIT courseware or when they guided a student through a mastery test.

The TICCIT developers had hoped that their program would enable teachers to adopt a new role as manager and advisor. A teacher under the TICCIT program would guide students toward learning objectives and help students to plan and to evaluate appropriate strategies for learning (Black, 1974; Bunderson, 1973). Seldom could instructors at the demonstration sites afford to spend time on these activities. Math instructors devoted just one percent of their time to counseling students on their course progress, and English instructors just six percent of their time to the same activity. Considering assistance on system procedures as advice on strategies would double these percentages, but it still seems clear that teachers at the demonstration sites did not fulfill the role foreseen by the TICCIT developers.

Instructor and Proctor Activities under the TICCIT Program

	Percentage of Time Engaged in Task			
	Math		English	
Tasks	Instructors	Proctors	Instructors	Proctors
Answering student questions on content (explaining material)	34		29	
Monitoring tests (checking answers on mastery tests)	31		15	
Observing class (circulating among students)	10	43	10	28
Performing managerial work (taking attendance, keeping records)	8	8	8	10
Holding discussions with other staff, visitors, instructors, observer	7	16	7	2
Attending to system failures (fixing student data areas, consulting with technicians)	6	4	3	2
Assisting students on system procedures (showing students how to use system)	1	20	8	28
Counseling students (advising students on course progress)	1		6	
Grading assignments (reading and marking student themes)			6	
Administering off-line tests (drilling students in spelling)			2	20
Fulfilling miscellaneous duties (making announcements, etc.)			2	2
Working at terminal		2		1
Not present in classroom		7	5	6
Number of observations	36	33	36	36

Table 8.2

To a large extent, instructors under the TICCIT program performed those tasks demanded by the situation. Students often required further explanation of the material available on the TICCIT system. It was common, especially in math classes where there was a high student-teacher ratio, to see a teacher working with a student on a third-test attempt while other students waited for assistance. The pattern of correlations between number of students present and teacher time spent on various tasks reinforce this point. Instructors tended to devote more time to answering student questions on content, monitoring tests, and performing managerial tasks when larger numbers of students were in attendance ($r = .14$, $.15$ and $.25$, respectively, for mainline TICCIT math classes). And they spent less time counseling students and assisting students on system procedures as attendance increased ($r = -.26$ and $-.22$, respectively). Similarly, proctors spent greater amounts of time on assisting students in the mechanical details of system use when more students attended their TICCIT math classes ($r = .64$).

It may be that the TICCIT program was sufficient to support independent student study but that neither faculty nor students could adapt to this new learning environment. After years of instruction delivered in a conventional manner, students perhaps found themselves unable to take full advantage of the learner control offered on the TICCIT system. Certain percentages of students did complete courses on the TICCIT system, attain higher scores on achievement posttests than comparable students in lecture-discussion sections, and they did so in less time than would ordinarily be required for attending classroom lectures and discussions. Most community college students enrolled in courses on the TICCIT system, however, simply failed to complete the requirements for course credit. Perhaps instructors trained to serve as a subject matter resource persisted in that role with the TICCIT program and failed to provide the counsel and advice on learning strategies which may have been necessary for all students to benefit from the TICCIT program. Perhaps instructors with special skills in promoting effective learning strategies on instructional systems such as the TICCIT system could help the program to reach a greater proportion of students. The strongest evidence for such a position would be a counterexample to the results of this demonstration.

8.2 Faculty Acceptance

In their recent review of the literature on teacher attitudes, Stern and Keislar (1977) concluded that teacher attitudes do make a difference in the teaching-learning process and that teacher attitudes can be altered. Both of these conclusions bear implications for innovative educational programs such as the TICCIT project. The outcomes obtained with a program may be attributed, at least in part, to instructor attitudes toward that program. Strong teacher resistance could sabotage another wise effective project or high teacher enthusiasm might be the real explanation for observed positive outcomes. Moreover, a program itself may lead to changes in teacher attitudes. Demonstrated improvements in student performance, for example, might be expected to generate teacher support for a program. To document the initial receptivity of faculty and their subsequent reactions to the TICCIT program, assessing teacher attitudes became a part of the evaluation for the TICCIT project.

It has been suggested that the resistance of classroom teachers represents the greatest single impediment to the widespread implementation of instructional technology in our schools (Armsey and Dahl, 1973). Anastasio and Morgan (1972) offered several plausible explanations for this resistance as it applies to computer-assisted instruction: fear of the changes which result from a technology as complex as the computer; ignorance of the computer's potential and limitations; and the clash of values that arises from the teacher's perception of the computer as a replacement for personal interactions with students. Tobias (1968) had earlier noted that the introduction of automated devices into schools poses a threat to teachers, and others (e.g., Olivier, McLean, Brahan & Payne, 1975) have stressed the importance of teacher attitudes in determining the impact of innovative curricular programs based on computers.

If the TICCIT program succeeded in fostering positive faculty attitudes, this alone could very well constitute a significant contribution to the field of instructional technology. It would also reflect the positive judgment of those closest to the project, instructors and administrators at the demonstration sites, on the quality of the program.

8.2.a Baseline Attitudes

Assessing changes in attitudes and understanding initial receptivity required a survey of faculty attitudes conducted prior to the implementation of the TICCIT program. Such a survey was conducted in the early stages of the project (Alderman & Mahler, 1977). However, the response rate for this survey was low as faculty completed and returned only one-third of the total number of forms distributed. The conclusions drawn from that initial survey were therefore tentative and perhaps unrepresentative of the colleges' beliefs about educational practices and their receptivity toward computer-assisted instruction. Still, the initial faculty survey helped to focus later questions on those aspects of educational practices related to the premises of the TICCIT program and to improve procedures for selecting items and distributing questionnaires.

A second faculty survey preceded the introduction of the TICCIT system into the community colleges. This survey took place in the spring term of the 1973-74 academic year; the TICCIT system was installed in the summer term of the same academic year. The number of questions included on the survey was less than one-half of the number on the original form. And the response rate was over twice that obtained with the initial survey. At the time of this second survey, faculty had attended general orientation sessions about the TICCIT program, and some had participated in specifying content coverage and planning for the demonstration. Administrators and instructors certainly knew more about the TICCIT project and perhaps were better able to appreciate the intent of the questions on the survey. A questionnaire specifically focused on matters related to the TICCIT program, the further refinement of a tried and proven version of a faculty attitude survey, college faculty informed about the TICCIT project, questionnaire distribution prior to the installation of TICCIT systems, and a high response rate, all of these factors provide reason to accept the results which follow as representative of initial faculty attitudes.

Instrument. The survey form (see Appendix I, Form 02T) was a refinement of the original attitude questionnaire. It contained essentially two sections: the first dealt with assumptions about educational practices implicit in the design of the TICCIT program and the second concentrated on popular beliefs about computer-assisted instruction. Items in the first section sampled opinions about course objectives (items 1-3), curriculum structure (items 4-7), student management (items 8-11), practices for grading and testing (items 12-15), and institutional receptivity to innovation (items 16-17). Statements in the second section concerned faculty familiarity with computers (items 18-19), the impact of CAI on the teacher's role (items 24, 25, 30), CAI potential for student learning (items 21-23, 26, 27), and global judgments of CAI's place in education (items 20, 29). Throughout the instrument there was emphasis on the learner control and mastery testing so important in the design of the TICCIT program (see Bunderson, 1973).

Each item on the survey was a statement accompanied by a five-point response scale for indicating extent of agreement. So as to inhibit the formation of response sets, there were statements phrased in both a positive (e.g., "CAI tailors instruction to the individual student.") and negative (e.g., "CAI is a potential threat to the jobs of faculty members.") manner. The scores assigned to responses ranged from five for strong agreement with the statement to one for strong disagreement. In addition to these items, there was one question about faculty priorities in the evaluation of CAI (item 31) and another about their knowledge of the TICCIT program (item 32).

Response Rate. The survey along with a letter of explanation and a reply envelope was mailed directly to the 314 faculty members at the colleges. After four weeks letters were sent to 97 faculty members who had not yet responded. Within seven weeks 239 completed forms had been returned for a response rate of 76%. Undoubtedly, the shortened length of the survey and the anonymity of the form contributed to the high rate of return.

The survey did require information about each respondent's college, division, department and position. And there was some fluctuation in the response rate across these categories. For example, the response rate from Alexandria was 72% and from Phoenix 79%; math instructors returned 83% of the forms sent to them while English instructors returned 71%. But the rate for any given category of faculty members tended to be close to the average, as might be expected from the high response rate overall. Since over three-fourths of the faculty responded to the survey, the data should yield a fair description of faculty opinions about educational practices and of faculty beliefs about computer-assisted instruction. The candor of the comments made on the survey further suggest that this description is accurate as well as fair.

Analysis. Much of the richness in these data can be found at the item level. Simple descriptive statistics, namely the mean and standard deviation of the responses to an item, suffice for revealing the point of consensus and extent of variation in faculty attitudes on a particular matter. Yet it is also helpful to consider the dimensions underlying these responses to individual items. The pattern of responses can reveal the major constructs upon which faculty base their opinions. Thus, the results of the survey will be presented through a factor analysis of the data and through descriptive statistics for each item.

Separate factor analyses were performed for the two sections of the survey. Previous results had indicated that faculty opinions about educational practices and their attitudes toward computer-assisted instruction involved independent affective dimensions (see Alderman & Mahler, 1977). In other words, the basic structure behind faculty responses to statements about educational practices overlapped little with the pattern of responses to statements about computer-assisted instruction. The dimensions depicted by factor analysis would thus be nearly the same whether the analysis was conducted for both sections together or for each section by itself. Because the two sections concerned two quite different subjects, we preferred to conduct separate factor analyses.

Of the total number of 239 forms returned by faculty, there were 215 with a response to every statement in the first section of the survey and 223 with a response to every statement in the second section. The item correlation matrix for the 17 statements on educational practices was therefore based on the data from 215 respondents. Similarly, the item correlation matrix for the 13 statements about computer-assisted instruction was based on the data from 223 respondents. Each of these item correlation matrices was subject to a principal components analysis with varimax orthogonal rotations.

Beliefs about Educational Practices. Four major factors emerged from the principal components analysis of the first section of the survey. The eigenvalues for these four factors were 2.82, 2.35, 1.59 and 1.21. Since eigenvalues in relation to the total number of items give the amount of variance accounted for by a factor analysis, the four factors accounted for 47% of the total variance in the item correlation matrix. The varimax solution itself is shown in Table 8.3. Most items clearly loaded under just one factor: an item's highest loading came under one factor with much lower loadings elsewhere. For example, the first item had a loading of .69 under Factor II and loadings of -.03, -.03 and .12 under the other three factors. And the seventeenth item had a loading of -.82 under Factor IV with much lower loadings, .04, .13 and .02, under other factors. The few exceptions to this pattern (i.e., items 2, 3 and 14) do seem to belong under multiple factors. The general factor structure given in Table 8.3 suggests four dimensions for describing faculty beliefs about educational practices. According to the statements under each factor (shown in Table 8.4), we've chosen to label the four dimensions Student Focus, Subject Matter Emphasis, Receptivity to Innovation, and Incentives for Student Work.

The first factor accounts for the most variance and seems to reiterate the importance of a focus on students at community colleges. Because the statements under this factor, as listed in Table 8.4, suggest the student is the focal point for curricular decisions and interpersonal contacts, Factor I has been labeled Student Focus. The items most prominent under this factor concern discussions among students and informal interactions between students and faculty. These items (items 7 and 11) were among those with the highest mean and smallest standard deviation:

Faculty Attitudes toward Educational Practices
Rotated Factor Matrix
(after varimax orthogonal rotation)
Alexandria and Phoenix
Spring 1974

Item Number	Factor Loadings			
	I	II	III	IV
1	-.03	.69	-.03	.12
2	.41	.44	.07	-.35
3	.39	.36	.09	-.10
4	.10	.56	-.04	.12
5	.50	.26	.32	.03
6	.56	.08	.08	-.20
7	.75	-.03	-.06	.20
8	-.04	.17	.09	.73
9	.12	.05	.09	.60
10	.58	.04	-.15	-.13
11	.67	.07	-.02	.04
12	.11	.71	-.18	.01
13	.43	-.23	.22	.16
14	-.10	.57	-.13	.41
15	-.14	.10	-.32	.49
16	.04	-.09	.84	.04
17	.04	.13	-.82	.02

Table 8.3

Faculty Attitudes toward Educational Practices
Varimax Primary Factors
Alexandria and Phoenix
Spring 1974

Item Number	Stem	Factor Loading	Mean	sd
Factor I:	Student Focus	(N - 215)		
7	Discussions among students contribute to their learning.	.75	4.50	.65
11	Informal interactions between students and faculty are an important part of education.	.67	4.45	.57
10	Students can benefit from increased flexibility and responsibility for their own instruction.	.58	3.87	.80
6	College instruction should allow each student to proceed at his/her own pace.	.56	3.61	1.00
5	Student feedback is essential in preparing new course material.	.50	4.34	.75
13	A student's progress is more important than his final level of achievement.	.43	3.44	1.05
2	The development of self-confidence and a sense of accomplishment should be an essential part of every course.	.41	4.64	.56
3	College courses must develop students' interest in and appreciation of the subject.	.39	4.17	.86
Factor II:	Subject Matter Emphasis			
12	Students should be evaluated against a well-defined criterion of knowledge or skills.	.71	4.00	.85
1	There are specific concepts or skills which students in all sections of a course must master.	.69	4.61	.64
14	Testing is an important and integral part of the educational process.	.57	4.00	.85
4	The primary basis for the organization of a course should be the intrinsic organization of the subject matter.	.56	3.60	.95
2	The development of self-confidence and a sense of accomplishment should be an essential part of every course.	.44	4.64	.56
Factor III:	Receptivity to Innovation			
16	It has not been possible for new ideas about educational practice to receive a hearing at this institution.	.84	1.78	.89
17	Administrators or department chairmen generally encourage faculty to experiment with new courses and/or teaching methods.	-.82	3.99	.81
Factor IV:	Incentives for Student Work			
8	Without close faculty supervision, many students at this college would not be able to sustain sufficient motivation to complete their studies.	.73	4.05	.91
9	Most students need peer competition as an incentive for working and learning.	.60	3.31	.97
15	The responsibility for a student's grade must rest with the instructor.	.49	3.33	1.26

Table 8.4

faculty stressed the role of interpersonal contacts in teaching community college students. Yet computer-assisted instruction might threaten just such discussions and informal interactions. The TICCIT program did promise students greater involvement in their own learning and an opportunity for instruction geared to each individual's rate of learning. Such goals would be consistent with a student focus (items 10 and 6 under Factor I in Table 8.4), but faculty endorsement of these practices is lower than the importance attached to interpersonal contacts. Faculty also concurred that courses should develop students' self-confidence and their appreciation of the subject matter (items 2 and 3 in Table 8.4). These, too, were among the goals of the TICCIT program. However, a common criticism of computer-assisted instruction in general has been expressed as doubt of its potential for positive impact on the affective aspects of student learning. Despite the consistency of the goals of the TICCIT program with a student focus, there would seem to be possible points of conflict with faculty beliefs about educational practices.

The statements grouped under Factor II deal with several of the premises of the mastery learning scheme inherent to the TICCIT program and reflect on emphasis on the subject matter of a course. These statements (items 12, 1, 14 and 4 under Factor II in Table 8.4) repeated basic tenets of mastery learning: the use of a well-defined criterion of knowledge or skills for evaluating students; the importance of students mastering specific concepts; the role of testing in learning; and the structure of the subject matter as the principle basis for course organization. The TICCIT program depended on these tenets, and faculty seemed to believe in them as sound practices. The second item on the survey, already reported under Factor I, appears again alongside statements about student mastery of the subject matter. This suggests both the awareness of faculty about mastery learning and the strategy by which the developers of the TICCIT program hoped to promote self-confidence and a sense of accomplishment among students. The factor itself seems to represent the counterpart of a Student Focus as it stresses the importance of the subject matter in learning.

The third dimension of faculty opinions about educational practices is Receptivity to Innovation. The two items under this factor were adapted from another instrument (Peterson, Centra, Hartnet & Linn, 1970) specifically for their emphasis on a college's openness to change. It was to be expected that colleges receptive to the TICCIT program also would be open to new ideas about educational practice (item 16) and would encourage faculty to experiment with new courses and teaching methods (item 17). Over eighty percent of the faculty members who responded to the survey (see Appendix T for response distributions by item) perceived their institution as receptive to innovations. In this respect the two community colleges constituted fertile ground for a demonstration of the TICCIT program.

Factor IV contains statements about student management. Faculty supervision (item 8), peer competition (item 9) and grades (item 15) might all be viewed as incentives for student work. Faculty agreed that close supervision helps students by sustaining their motivation to complete their students. There was far less agreement about the need for peer competition among students and the responsibility for student grades. The importance associated with close faculty supervision reiterates the emphasis placed on interpersonal contacts in student learning (items 7 and 11 under Factor I). And, again, this faculty opinion suggests a possible conflict should the TICCIT program supplant instructors. If the TICCIT program eliminated peer competition or automatically assigned student grades, nearly one-fourth of the faculty might welcome such changes and another fourth would at least voice no objections (see Appendix T).

The general description of faculty attitudes toward educational practices, as given above and supplemented by the descriptive statistics in Table 8.4 and the item response distributions in Appendix T, seems to hold across academic divisions and positions. Table 8.5 presents descriptive statistics at the item level for all respondents, for academic divisions, and for instructors and administrators. The item means for all respondents stay within five-hundredths of a point of the respective means for respondents with complete data in the first section of the survey. Faculty attitudes also appear to be consistent across divisions or positions: item means vary little across these categories. However, administrators did endorse self-paced instruction (item 6) and definite criteria for evaluating students (item 12) more strongly than instructors had. And faculty members from the natural sciences seemed to place greater emphasis on the subject matter (items 12, 1 and 4) than did their colleagues from other disciplines. Indeed, this dimension reflected the widest discrepancies among faculty divisions in their opinions about educational practices. But even where differences of opinion existed among the major academic divisions or between instructors and administrators, these differences involved the extent of their agreement on a matter rather than the advocacy of opposite extremes.

Faculty Attitudes toward Educational Practices
Responses across Divisions and Positions
Alexandria and Phoenix
Spring 1974

	Item Number	All Respondents (N ≅ 239)		Natural Sciences (N ≅ 38)		Social Sciences (N ≅ 24)		Humanities (N ≅ 58)		Applied Studies (N ≅ 66)		Instructors (N ≅ 170)		Administrators (N ≅ 29)	
		Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd
Factor I: Student Focus	7	4.50	.65	4.49	.64	4.38	.81	4.64	.58	4.34	.68	4.46	.69	4.66	.54
	11	4.44	.59	4.56	.50	4.36	.69	4.44	.59	4.34	.58	4.42	.59	4.62	.49
	10	3.88	.81	3.87	.65	3.96	.92	3.84	.83	3.79	.87	3.80	.83	4.14	.73
	6	3.62	1.00	3.55	.94	3.62	.79	3.55	.93	3.41	1.15	3.53	1.02	4.07	.74
	5	4.32	.77	4.33	.80	4.12	1.07	4.25	.73	4.28	.77	4.28	.80	4.38	.81
	13	3.48	1.05	3.24	1.09	3.54	1.01	3.64	.96	3.41	1.17	3.54	1.05	3.45	1.04
	2	4.65	.56	4.66	.57	4.46	.76	4.69	.50	4.68	.53	4.62	.59	4.76	.43
	3	4.17	.87	4.23	.92	4.42	.81	4.20	.93	4.01	.88	4.17	.87	4.10	.84
Factor II: Subject Matter Emphasis	12	3.98	.88	4.28	.71	3.56	1.20	3.95	.89	4.01	.81	3.95	.89	4.31	.65
	1	4.60	.66	4.84	.36	4.38	.70	4.47	.75	4.71	.57	4.60	.66	4.65	.66
	14	4.00	.83	4.36	.58	4.12	.85	3.95	.86	3.93	.85	4.01	.81	4.10	.88
	4	3.60	.99	3.82	.94	3.50	1.25	3.84	.83	3.65	.95	3.63	.96	3.41	1.19
	2	4.65	.56	4.66	.57	4.46	.76	4.69	.50	4.68	.53	4.62	.59	4.76	.43
Factor III: Receptivity to Innovation	16	1.77	.87	1.64	.89	2.12	1.05	1.74	.96	1.67	.64	1.79	.90	1.59	.62
	17	3.99	.80	4.13	.85	3.69	.82	4.03	.85	4.17	.69	3.99	.82	4.03	.56
Factor IV: Incentives for Student Work	8	4.03	.91	4.11	.82	4.21	.87	4.17	.94	4.00	.82	4.07	.89	4.07	.91
	9	3.29	1.01	3.59	.81	2.92	1.14	3.56	.89	3.15	1.00	3.36	.99	3.17	1.18
	15	3.29	1.27	3.67	1.37	3.71	1.10	3.05	1.21	3.31	1.31	3.32	1.27	3.21	1.32

Table 8.5

On the whole, faculty responses to the first section of the survey indicated attitudes supportive of the premises inherent to the design of the TICCIT program. Faculty generally agreed with statements reflecting the basic tenets of mastery learning, and the mastery tests and hierarchical content structure adopted for the TICCIT program incorporate design features of mastery learning. As viewed by their faculty, the colleges selected as demonstration sites for the TICCIT project were receptive to educational and curricular innovation. The colleges' active participation in the project certainly confirms this view. Since most faculty did not perceive peer competition as essential to student learning and did not see grades as a necessary responsibility of the instructor, there was leeway for the TICCIT program in assuming a role in student management.

The clearest and most prominent dimension behind faculty attitudes toward educational practices was a focus on the interests of the student. Faculty seemed to base their responses on what they considered best for the student. And they certainly believed in the importance of personal interactions for student learning. Over 90% of the faculty agreed that discussions among students and informal interactions between students and instructors contributed to the educational process. A clash of values might arise if the TICCIT program inhibited such interactions, or faculty might readily accept the TICCIT program if it instead facilitated interpersonal contacts. This dimension of Student Focus had also appeared in the factor analysis conducted for the original faculty attitude survey (Alderman & Mahler, 1977), and a point made in that earlier report perhaps warrants repetition here. Often innovative programs attempt to exploit the unique potential of a particular delivery mechanism, yet faculty acceptance would seem to depend on the extent to which a program addresses student needs and perhaps takes advantage of a student's unique potential for learning. The TICCIT program did seek to exploit each student's capacity for learning through its learner control and its mastery approach to instruction.

Attitudes toward CAI. In contrast to the four factors found to underlie faculty beliefs about educational practices, two factors sufficed for describing faculty attitudes toward computer-assisted instruction. A break in the magnitude of latent roots after the second root had determined the number of factors to be rotated. The eigenvalues associated with these two factors were 5.24 and 1.54. Thus, the varimax solution shown in Table 8.6 accounted for 52% of the total variance. The two dimensions to this solution reflect general attitudes toward CAI and familiarity with computers.

Items that dealt with CAI (items 20-30) loaded under Factor I in the principal components analysis conducted for the second section of the survey. Unlike items from the first section of the survey which had means near the extremes of the response scale (above four or below two on the five-point response scale), all of the statements in the second section resulted in means near the scale's mid-point of the scale. Table 8.7 presents the item stems along with their respective factor loadings, means, and standard deviations. The only statements with which a majority of the faculty agreed were those about the strength of the immediate feedback available with CAI (item 26), the potential for CAI to relieve

Faculty Attitudes toward CAI
Rotated Factor Matrix
(after varimax orthogonal rotation)
Alexandria and Phoenix
Spring 1974

Item Number	Factor Loadings I	II
18	.07	.91
19	.14	.91
20	.64	.28
21	.69	.10
22	-.55	-.07
23	.72	.02
24	-.31	.05
25	.64	.16
26	.74	.15
27	.79	.08
28	-.63	-.06
29	-.73	-.15
30	.76	.20

Table 8.6

Faculty Attitudes toward CAI
Varimax Primary Factors
Alexandria and Phoenix
Spring 1974

Item Number	Stem	Factor Loading	Mean	sd
Factor I:	General Attitudes toward CAI	(N = 223)		
27	CAI will make students more active agents in their own education.	.79	3.57	.79
30	CAI can make better and fuller use of instructors' capabilities.	.76	3.58	.82
26	Immediate feedback to students makes CAI a highly desirable instructional method.	.74	3.90	.74
29	CAI is a passing fad.	-.73	2.46	.77
23	CAI tailors instruction to the individual student.	.72	3.40	.88
21	CAI allows students to assume greater responsibility for their own learning.	.69	3.60	.80
20	CAI is one of the most significant developments in education today.	.64	3.15	.90
25	CAI can relieve instructors of routine duties.	.64	3.70	.92
28	Student interest in or appreciation of a subject can not be developed with CAI.	-.63	2.63	.83
22	Computers are too impersonal to replace conventional instruction.	-.55	3.30	1.00
24	CAI is a potential threat to the jobs of faculty members.	-.31	2.52	1.05
Factor II:	Familiarity with Computers			
18	I have become familiar with computers through my previous experience.	.91	2.88	1.40
19	I feel comfortable working with computers.	.91	2.86	1.24

Table 8.7

instructors of routine duties (item 25), and student responsibility for their own learning under CAI (item 21). For each of the other eight items under Factor I the modal response was "not sure" (see Appendix T). And over 50% of the faculty responded "not sure" to the two statements about the general significance of CAI (items 20 and 29).

Factor II has been termed Familiarity with Computers since the two statements under this factor deal with experience and work with computers (items 18 and 19). Faculty responses to these two statements revealed much of the reason for their uncertainty about CAI. Better than 40% of the faculty disavowed familiarity or comfort when confronted by a computer. Add to these respondents anyone who chose "not sure" and we find the majority of faculty members probably lacked a background of experience with computers. This lack of computer experience perhaps explains why such diverse items about CAI loaded under one general factor: faculty had no practical basis for differentiating among the statements which appeared under Factor I (see Table 8.7). The frequency of neutral responses to statements about CAI seems appropriate and fair given faculty's prior exposure to computers.

Table 8.8 presents descriptive statistics for statements in the second section of the survey. Although there was little difference in attitudes toward CAI across divisions, there was a pronounced difference between instructors and administrators. Administrators tended to look upon CAI more favorably than did instructors. Again, the responses to statements included under Factor II may provide a plausible explanation for the results under Factor I. Administrators' greater confidence and hope in CAI might be attributed to their greater familiarity with computers.

Faculty Attitudes toward CAI
Responses across Divisions and Positions
Alexandria and Phoenix
Spring 1974

	Item Number	All Respondents (N ≅ 239)		Natural Sciences (N ≅ 38)		Social Sciences (N ≅ 24)		Humanities (N ≅ 58)		Applied Studies (N ≅ 66)		Instructors (N ≅ 170)		Adminis-trators (N ≅ 29)	
		Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd
Factor I: Attitudes toward CAI	27	3.57	.79	3.59	.72	[illegible]	[illegible]	3.34	.79	3.58	.78	3.46	.78	4.07	.64
	30	3.59	.82	3.43	.72	[illegible]	[illegible]	[illegible]	.79	3.68	.73	3.51	.81	4.07	.58
	26	3.89	.74	4.00	.66	[illegible]	[illegible]	[illegible]	.83	3.89	.66	3.83	.75	4.28	.58
	29	2.47	.77	2.51	.68	[illegible]	[illegible]	2.70	.71	2.35	.79	2.57	.75	1.93	.64
	23	3.41	.88	3.32	.87	[illegible]	[illegible]	3.33	.94	3.31	.89	3.34	.88	3.66	.88
	21	3.59	.80	3.73	.76	[illegible]	.70	3.35	.78	3.55	.86	3.51	.81	3.93	.52
	20	3.14	.90	3.00	.70	3.00	1.00	2.98	.87	3.29	.99	3.05	.92	3.69	.79
	25	3.71	.91	3.51	1.03	3.58	.86	3.56	1.01	3.82	.80	3.68	.89	4.00	.87
	28	2.63	.82	2.73	.76	2.65	.81	2.77	.76	2.63	.78	2.72	.77	2.14	.78
	22	3.32	1.01	3.41	.88	3.28	1.04	3.55	1.00	3.31	1.04	3.42	1.00	2.76	.90
	24	2.53	1.05	2.95	.90	2.75	1.13	2.68	1.00	2.18	1.01	2.61	1.04	2.24	1.10
Factor II: Familiarity with Computers	18	2.86	1.40	3.14	14.0	2.88	1.45	2.50	1.30	2.83	1.44	2.75	1.40	3.38	1.32
	19	2.83	1.24	2.97	1.28	2.72	1.25	2.47	1.13	2.97	1.30	2.72	1.24	3.62	.89
Priorities for Success	31(a)	3.49	1.06	3.58	1.16	3.32	1.09	3.59	.96	3.58	1.12	3.47	1.07	3.52	.97
	(b)	3.59	1.18	3.64	1.25	3.68	1.09	3.55	1.13	3.37	1.27	3.57	1.23	3.93	1.01
	(c)	2.64	1.08	2.72	1.04	2.48	1.14	2.50	1.07	2.78	1.09	2.66	1.09	2.55	1.10
	(d)	4.09	1.21	3.69	1.29	4.16	1.25	4.32	1.04	4.02	1.26	4.11	1.22	3.86	1.22
	(e)	1.38	.83	1.47	1.01	1.64	.97	1.30	.73	1.49	.90	1.44	.87	1.34	.88

Table 8.8

The last question on the faculty attitude survey (item 31) had asked respondents to order several considerations for judging the success of CAI according to their own priorities. They ranked five alternatives from highest (coded 1) to lowest (coded 5). In order, faculty priorities were: student achievements; student attitudes; faculty acceptance; technical capabilities and reliability of the computer system; and finally, cost. These priorities for judging the success of CAI certainly appear consistent with the student focus maintained by community college faculty.

8.2.b Reactions to the TICCIT Program

Another survey of faculty attitudes was conducted in the spring term of the 1975-76 academic year. This was nearly two years after the installation of TICCIT systems in the community colleges and toward the conclusion of the first year of the demonstration period. The TICCIT program had supported math courses for four semesters at Phoenix and for five quarters at Alexandria. English courses had been offered on the TICCIT system for almost one full year. Moreover, the colleges had incorporated the TICCIT program into their curriculum and faculty had a definite basis for responding to questions about the program. The purpose of this third faculty attitude survey was to document instructors and administrators' reactions to the TICCIT program.

Instrument. The survey itself had a question about faculty exposure to the TICCIT program, two questions about general familiarity with computers, 33 questions posed as statements about the TICCIT program accompanied by a response scale for indicating extent of agreement, and a final question on faculty's perceptions of TICCIT's impact (see Appendix I, Form 003). The first question on exposure to the TICCIT program established the respondent's sources of information about the TICCIT program. It was a list of activities by which faculty might have learned about the program, such as teaching a TICCIT section of a course or simply reading memos about the project (item 1, parts a-i). Respondents checked those activities that formed their basis for reactions to the TICCIT program. The next two questions (items 2 and 3) dealt with faculty exposure to computers in general. These questions were retained from the earlier survey of initial attitudes toward computer-assisted instruction and represented the factor already labeled Familiarity with Computers (see Table 8.7, Factor II).

The statements about the TICCIT program were either adapted from earlier surveys or suggested by participants' comments. Statements taken from the previous faculty survey had the general phrase "computer-assisted instruction" replaced by a specific reference to the TICCIT program in order to elicit opionions about this particular program. For example, "CAI relieves instructors of routine duties" became "TICCIT relieves instructors of routine duties." Comments made by faculty and students prompted the development of additional items. For example, faculty often cited the self-paced nature of the TICCIT program as one of its primary advantages while students at times complained that instruction available only on the TICCIT system was less convenient for them than the traditional combination of classes and homework exercises. Both statements can be found in the third faculty attitude survey (items 9 and 4). The broad topics covered in the survey might be represented as student use of the TICCIT system (items 4-12, 31 and 32), instructors' tasks in relation to the

TICCIT program (items 13-19), the TICCIT curriculum and its delivery (items 22-30), and global judgments of the program (items 20, 21, 33-36).

As with its predecessor, the survey presented questions in the form of statements followed by a five-point response scale. Responses could range from strong agreement to strong disagreement with the statement, coded from five points to one point, respectively. The scale's mid-point was a "not sure" response scored as three points. These point assignment subsequently determined the means and standard deviations reported below for each item on the survey. So as to discourage the mere repetition of the same response across items, there were two statements phrased in a negative manner for every three positive statements about the program (e.g., "The TICCIT curriculum is dull and fails to excite students about the subject matter" and "TICCIT promotes self-confidence and a sense of accomplishment among students").

The final question the survey (item 37) also had a five-point response scale but it asked for faculty members' own evaluation of the impact of the TICCIT program. It sought their assessment of TICCIT's impact on student achievement, student attitudes toward the subject matter, course completion rates, the quality of student-instructor interactions, and the quality of interactions among students. Faculty indicated to what extent they thought the TICCIT program had affected these aspects of the educational process.

Response Rate. The procedure was distributing the survey was the same as that for the survey of beliefs about educational practices and predispositions toward computer-assisted instruction. A cover letter, the survey, a reply envelope and a separate postcard on the status of each form were sent to all staff members at the community colleges. After one month another letter went out to those faculty members who had not yet responded. A total of 204 completed forms had been returned within eight weeks of the survey's distribution date. This represented a response rate of 52% since 391 staff members had received forms for completion.

This response rate falls midway between the percentages of forms returned in the first and second faculty attitude surveys. It is substantially higher than the one-third response rate for the first survey (Alderman & Mahler, 1977) due to the brevity and anonymity of this third survey. Yet the rate is lower than the overall 76% return achieved in the second survey. Since faculty at both colleges returned about half of the forms sent to them, there was not a difference by demonstration site. Instead, we believe the response rate can be attributed to the need for reactions to the TICCIT program. Those faculty members unfamiliar with the program simply did not respond. Responses came from faculty who had contact with the program and thus had a basis for reacting to statements about it. Nearly every member of the mathematics and English departments at the colleges submitted replies to the survey. It seems probable, therefore, that the results depict faculty reactions fairly.

Exposure to the TICCIT Program. The activities checked by respondents as contributing to their knowledge of the TICCIT project attest to their familiarity with the program. Nearly one-seventh of the total number of respondents had themselves worked at a TICCIT terminal. The majority of those faculty members responding to the survey had attended an orientation session about the project (55%), read articles or memoranda that dealt with the program (57%), observed the TICCIT program in operation (58%), spoken with students enrolled in a TICCIT class (67%), and discussed the project with their colleagues (77%).

Few faculty members had direct experience with the TICCIT program. The program itself precluded widespread faculty participation by its focus on mathematics and English courses. Only instructors in those departments had an opportunity for close, daily contact with the program. And most of these instructors responded to the survey. Others relied heavily on conversations with students and colleagues in forming impressions of the program. Thus, the attitudes documented through this third faculty survey reflect reactions based primarily on indirect exposure to the TICCIT program.

Dimensions and Contrasts. Eliminating incomplete forms from the total number of 204 surveys left 184 responses as a basis for factor analysis. An item correlation matrix for the 35 statements about the TICCIT program was calculated from this data base, and a principal components analysis with varimax orthogonal rotations was performed. The analysis revealed five major dimensions for faculty attitudes toward the TICCIT program. Together, these five factors accounted for 52% of the variance in faculty responses to individual items. The respective eigenvalues were 11.55, 1.94, 1.70, 1.50 and 1.35. As had been observed in the discussion of faculty attitudes toward computer-assisted instruction in general, a single factor seems to dominate faculty perceptions and explain by far the most variance. The percentage of variance accounted for in the varimax solution for the third survey is almost identical to that accounted for in the varimax solution for the second survey's section on CAI. From a technical standpoint the results of the two analyses, one for attitudes toward computer-assisted instruction generally and the other for reactions to the TICCIT program specifically, seem consistent.

The varimax solution for faculty attitudes toward the TICCIT program appears as Table 8.9. Nearly half of the items attained their highest loading under the first factor. A steadily smaller number of items loaded under each of the other four factors. This pattern reiterates the relative importance of the first factor in describing faculty reactions. Indeed, the structure of the rotated factor matrix suggests that other factors may be related to the first. A cluster of items loaded to a moderate extent under both the first and third factors (items 11 and 33-36). This indicates that faculty tended to view the TICCIT program as a whole. Such a view might be expected from the fact that most faculty members relied on indirect exposure to the program for their knowledge about it.

Table 8.10 presents the statements associated with each of the factors in the varimax solution. These statements suggested the appropriateness of the label given to each factor: Global Judgments; Management of Instruction; Program Limitations; Teacher Role; and Familiarity with Computers. It should be understood that these dimensions reflect faculty perceptions of the TICCIT program. Responses revealed the opinions and beliefs of the college staff closest to the program, namely the instructors and administrators at the demonstration sites. These opinions and beliefs represent fairly faculty attitudes toward the project but cannot be regarded

Faculty Attitudes toward the TICCIT Program:
Rotated Factor Matrix
(after varimax orthogonal rotation)
Spring 1976

	Factor Loadings				
Item Number	I	II	III	IV	V
2	.00	.00	-.12	.07	.80
3	-.03	.00	.01	-.10	.77
4	-.23	.48	.34	-.30	-.04
5	.71	-.16	-.15	.03	.17
6	.66	-.15	-.02	.04	-.11
7	.57	-.22	.12	.20	.16
8	-.24	.63	.16	-.06	-.04
9	.63	.01	-.15	-.13	-.05
10	.60	-.41	.03	.16	-.01
11	.35	-.35	.39	-.21	.19
12	-.20	.26	.33	.16	-.24
13	.04	.21	.57	-.04	-.10
14	-.20	.12	.50	-.08	-.07
15	.40	-.48	-.12	.36	.18
16	.27	-.11	-.03	.72	.13
17	-.25	.47	.37	-.14	-.02
18	-.30	.53	.03	-.23	.20
19	.04	.00	.11	-.71	.18
20	.50	-.16	-.34	.06	.17
21	.67	-.26	-.34	.18	.18
22	-.07	.60	.21	-.05	.06
23	.68	-.18	-.22	.20	.03
24	.70	.04	.10	.01	-.19
25	-.61	.34	.38	.10	.05
26	.66	-.40	-.26	-.01	-.05
27	.65	-.28	-.33	.00	-.02
28	-.21	.11	.56	.01	.21
29	.41	-.18	-.15	.12	-.04
30	-.41	.37	.24	.07	.22
31	-.08	.62	.10	.12	-.10
32	.57	-.47	-.14	.23	.05
33	-.56	.28	.48	-.18	-.12
34	.55	-.22	-.48	.27	.08
35	-.45	.14	.49	-.22	-.25
36	.57	-.16	-.33	.33	.09

Table 8.9

Faculty Attitudes toward the TICCIT Program

Varimax Primary Factors
Alexandria and Phoenix
Spring 1976

Item Number	Stem	Factor Loading	Mean	sd
Factor I:	Global Judgments		(N = 184)	
5	Students become active in their own learning through the use of TICCIT.	.71	3.52	.94
24	Students exercise control over their instruction in the TICCIT program.	.70	3.62	.91
23	I consider the method of presentation on TICCIT to be innovative and effective.	.68	3.37	.95
21	I would recommend a TICCIT course to my students.	.67	3.24	1.12
26	The TICCIT program develops student interest in or appreciation of a subject.	.66	2.95	.80
6	The TICCIT program tailors instruction to the individual student.	.66	3.50	.94
27	TICCIT promotes self-confidence and a sense of accomplishment among students.	.65	3.18	.85
9	A student in a TICCIT class learns at his/her own pace.	.63	3.97	.84
25	The TICCIT curriculum is dull and fails to excite students about the subject matter.	-.61	2.84	.92
10	Working on the TICCIT system improves students' learning strategies and study habits in other courses.	.60	2.91	.83
32	Students find it easier to learn with TICCIT.	.57	2.82	.76
36	TICCIT is one of the most significant developments in education today.	.57	2.96	1.03
7	With TICCIT, students receive more individual attention from instructors.	.57	2.91	.93
33	The TICCIT program is not worth the dollars and space which this institution has invested in it.	-.56	3.10	1.09
34	TICCIT is a valuable resource for this institution.	.55	3.38	1.05
20	My colleagues seem to be favorably impressed by TICCIT.	.50	2.83	.98
29	Students who've completed a course on TICCIT have mastered all the specific concepts and skills covered in the TICCIT curriculum.	.41	2.93	.88
30	The TICCIT program does not allow for the integration and constant review of subject matter skills.	-.40	2.60	.92

Table 8.10(a)

Item Number	Stem	Factor Loading	Mean	sd
Factor II:	**Management of Instruction**			
8	In TICCIT classes students had to assume too much responsibility for their own progress in order to complete a course.	.63	3.01	.99
31	Breakdowns of the computer system disrupted students' learning on TICCIT.	.62	3.92	.89
22	As a pre-packaged program, the TICCIT curriculum affords instructors little flexibility in teaching a course.	.60	3.22	.93
18	It is difficult for an instructor to manage students' learning in TICCIT classes.	.53	2.97	.87
15	TICCIT helps to make better and fuller use of instructor's capabilities.	-.48	2.84	1.03
4	TICCIT is less convenient for students than a combination of classes and homework.	.48	2.91	1.08
17	Instructors in the TICCIT program spend too much time on mechanical problems and errors in the curriculum.	.47	3.33	.83
Factor III:	**Program Limitations**			
13	TICCIT is a potential threat to the jobs of faculty members.	.57	2.07	1.03
28	The TICCIT program teaches only lower level abilities.	.56	2.83	1.06
14	I would prefer to teach a regular section to a TICCIT section in my subject area.	.50	3.45	1.25
35	TICCIT is a passing fad.	.49	2.52	.98
Factor IV:	**Teacher Role**			
16	TICCIT relieves instructors of routine duties.	.72	3.16	1.07
19	An instructor has to meet greater demands on his/her time in a TICCIT class than in regular classes.	-.71	2.96	.73
Factor V:	**Familiarity with Computers**			
2	I feel comfortable working with computers.	.80	3.54	1.10
3	I have become familiar with computers from my previous experience.	.77	2.98	1.43

Table 8.10(b)

as a substitute for the data on TICCIT's impact on student performance or faculty duties presented elsewhere in this report.

The first factor, labeled Global Judgments, includes statements about various aspects of the TICCIT program. Five items necessitating an overall judgment of program quality appear under this factor (items 20, 21, 33, 34 and 36). Except that most faculty "would recommend a TICCIT course to [their] students" (item 21), the most frequent response to these global statements was "not sure" (see Appendix T for response distributions by item). Despite nearly two years of experience with the TICCIT system, college staff had yet to reach a consensus on the value of the program. But they had accepted the TICCIT program as a method for tailoring instruction to the individual student and involving students in their own learning. Faculty tended to agree that students became active in their own learning, exercised control over their instruction, received instruction tailored to the individual, and learned at their own pace (items 5, 24, 6 and 9). Since it had earlier been found that faculty beliefs about educational practices focus on the student, acceptance of the TICCIT program in terms of the flexibility afforded to students may be a positive outcome.

Those statements listed under Factor II in Table 8.10 seem to share an emphasis on the management of instruction. Most of these statements also reflect possible inconveniences due to the TICCIT program. The only clear consensus in this factor was that "breakdowns of the computer system disrupted students' learning on TICCIT" (item 22). And a malfunction in any form of instructional technology would be expected to cause a disruption. Otherwise the modal response to the items under the second factor was "not sure". The second most common response was evenly split between those indicating a positive reaction (disagreement with items 8, 18 and 4) and those indicating a negative reaction (agreement with items 22 and 17 and disagreement with item 15). Faculty had not formed a clear opinion of the program's impact on instructors and students' use of time. Indeed, the data on student and instructor activities sometimes point to efficient learning for those students capable of completing a course on the TICCIT system (see Table 7.7) and to greater instructor participation in the instruction of individual students (see Table 8.1), and at other times the data indicate student hours expended with little progress (see Figure 7.2) or the burden of monitoring tests assumed by instructors (see Table 8.2).

The statements grouped under Factor III might together be called Program Limitations since each statement presents an item stem phrased in a negative manner. Despite the direction of these stems, faculty responses depicted a generally favorable reaction. Faculty did not perceive the TICCIT program as a potential threat to their jobs (item 13). Similarly, they did not view the program as appropriate for only lower level abilities (item 28) or as just a passing fad (item 35). Consistent with responses given to other, closely related items (e.g., items 25 and 27), it would appear that faculty saw no limitations or personal threats inherent to the TICCIT program. Yet the number of respondents who indicated a preference for teaching a regular section of a course over a TICCIT section was twice as high as the number who preferred an assignment with the TICCIT program (item 14). Considering the nature of its statements and its apparent correspondence with the first factor (see Table 8.9), this third factor may be as much an artifact of specific item content as it is a true dimension of faculty attitudes toward the TICCIT program.

The fourth factor listed in Table 8.10 had two statements load highly under it. Both statements pertain to the role of teachers under the TICCIT program. Almost the same number of respondents were unsure about TICCIT's impact on routine duties as felt the program did relieve instructors of such tasks (item 16). By far the largest number of faculty chose the "not sure" response (57%) when asked whether "an instructor has to meet greater demands on his/her time in a TICCIT class than in regular classes (item 19)". The most frequent response to other questions about teacher role (items 15, 17 and 18) had also been "not sure". Apparently faculty awaited objective evidence on the results of the demonstration and resisted reaching judgments based primarily on indirect exposure to the TICCIT program.

The final factor given in Table 8.10 is a repetition of a dimension which had emerged in the analysis of the earlier faculty attitude survey (Table 8.7). That dimension was labeled Familiarity with Computers since it dealt with faculty's comfort in working with computers and their prior experience with computers. Again it is perhaps the most distinct component of faculty attitudes. The rotated factor matrix shows just two statements (items 2 and 3) that clearly belong under the fifth factor; these two statements had low loadings under every other factor, and no other statement reached even a moderate loading under Factor V (see Table 8.9). An equivalent percentage of faculty, approximately 40%, had agreed and disagreed with the statement "I have become familiar with computers through my previous experience (item 3)." Both the mean and standard deviation for responses to this statement (mean 2.98 and sd 1.43) came very close to those calculated for the earlier survey (mean 2.88 and sd 1.40). The majority of respondents, however, reported that they did feel comfortable working with computers: Over 100 faculty members agreed or strongly agreed with item 2 and fewer than 40 faculty disagreed or strongly disagreed (see Appendix T). In this respect the TICCIT project did affect opinions. The percentage of faculty uncomfortable working with computers dropped to half of its former level. At least the project dispelled apprehension of computers in general.

Table 8.11 presents descriptive statistics for each statement in the third faculty attitude survey and does so within academic divisions as well as for staff positions. Unlike the survey conducted prior to the installation of TICCIT systems at the community colleges, differences across divisions now seem apparent. Often one half of a standard deviation separates the mean response of faculty in the natural sciences and humanities from that of faculty in social sciences and applied studies (e.g., items 25, 33, 8 and 15). And the direction of the difference indicates a less favorable reaction to the TICCIT program within the divisions of natural sciences and humanities. The data on faculty attitudes included in the summaries for the natural sciences and the humanities came primarily from the responses of instructors in the math and English departments, the faculty best acquainted with the TICCIT program (a summary of responses from these departments and for 29 instructors who had taught TICCIT sections appears in Table 8.12). Indeed, the division of natural sciences should

Faculty Attitudes toward the TICCIT Program:
Responses across Divisions and Positions
Alexandria and Phoenix
Spring 1976

		All Respondents (N ≅ 184)		Natural Sciences (N ≅ 40)		Social Sciences (N ≅ 16)		Humanities (N ≅ 47)		Applied Studies (N ≅ 43)		Instructors (N ≅ 141)		Administrators (N ≅ 27)		Counselors (N ≅ 10)	
	Item Number	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd
Factor I: Global Judgments	5	3.52	.94	3.51	.67	3.81	1.11	3.21	1.02	3.58	.87	3.46	.96	3.89	.80	3.44	1.01
	24	3.63	.91	3.80	.84	3.53	.83	3.45	1.09	3.45	.79	3.57	.93	3.89	.80	3.70	.82
	23	3.38	.95	3.18	.97	3.38	.96	3.13	.88	3.49	.87	3.27	.96	3.89	.70	3.30	1.06
	21	3.25	1.13	2.98	1.07	3.56	1.32	2.96	1.05	3.47	1.17	3.16	1.16	3.78	.89	3.33	.87
	26	2.95	.81	2.70	.84	3.19	.75	2.69	.91	3.14	.64	2.91	.84	3.19	.62	3.00	.67
	6	3.50	.96	3.40	.92	3.50	1.26	3.33	1.00	3.64	.81	3.48	.96	3.54	1.07	3.67	.87
	27	3.19	.86	3.03	.82	3.50	.73	3.07	.89	3.23	.88	3.16	.89	3.37	.74	3.33	.50
	9	3.96	.85	4.15	.88	4.00	.73	3.69	.98	3.82	.75	3.90	.84	4.33	.73	4.30	.48
	25	2.84	.92	3.13	.94	2.60	.91	3.13	.99	2.58	.75	2.90	.94	2.67	.78	2.50	.85
	10	2.91	.83	2.75	.70	3.19	1.05	2.75	.92	3.02	.76	2.88	.86	3.04	.76	2.89	.78
	32	2.82	.76	2.55	.77	3.19	.91	2.77	.80	2.90	.61	2.81	.76	3.04	.65	2.33	.71
	36	2.96	1.03	2.62	.92	3.19	1.11	2.85	1.00	3.14	1.06	2.92	1.06	3.41	.84	2.50	.85
	7	2.90	.94	2.95	.86	3.19	1.11	2.80	.97	2.88	.91	2.90	.94	3.15	.95	2.22	.67
	33	3.09	1.10	3.44	1.01	2.88	.96	3.31	1.08	2.90	1.13	3.16	1.08	2.69	.93	3.40	1.43
	34	3.38	1.06	2.98	1.15	3.67	.98	3.30	1.04	3.56	1.02	3.33	1.08	3.77	.76	3.10	.99
	20	2.83	.99	2.88	1.00	2.94	1.09	2.49	.94	2.98	.87	2.75	.96	3.32	.95	2.44	1.13
	29	2.93	.89	2.90	.92	3.00	.97	2.80	.91	2.84	.78	2.86	.87	3.11	.97	3.50	.71
	30	2.59	.93	2.68	1.00	2.53	.92	2.98	.98	2.40	.78	2.69	.93	2.19	.68	2.20	.92
Factor II: Management of Instruction	8	3.01	1.00	3.35	1.15	2.56	.96	3.07	1.03	2.76	.78	3.07	.99	2.63	.93	3.11	1.05
	31	3.93	.89	3.95	.92	3.76	1.15	4.13	.84	3.67	.77	3.94	.89	3.75	.84	4.50	.71
	22	3.22	.93	3.48	1.00	3.13	.89	3.17	.97	3.02	.85	3.20	.93	3.52	.85	2.90	1.10
	18	2.98	.89	3.15	.91	2.80	.86	3.11	1.02	2.79	.59	3.04	.87	2.56	.85	3.40	1.08
	15	2.83	1.05	2.30	.95	3.38	1.09	2.55	1.07	3.18	.95	2.77	1.08	3.04	.96	2.90	.74
	4	2.89	1.11	3.27	1.11	2.88	1.20	3.00	1.10	2.63	.98	2.98	1.09	2.27	1.00	3.71	.95
	17	3.33	.83	3.58	.89	3.19	.91	3.43	.87	3.19	.79	3.39	.86	3.11	.70	3.30	.48
Factor III: Program Limitations	13	2.06	1.02	2.50	1.14	2.19	1.17	1.96	.84	1.81	.92	2.13	1.01	1.74	.94	1.90	1.10
	28	2.82	1.07	3.00	1.09	2.81	1.17	3.23	1.19	2.45	.79	2.89	1.05	2.81	1.18	2.40	.97
	14	3.45	1.28	3.95	1.01	3.94	1.44	3.47	1.33	3.02	1.37	3.49	1.32	3.28	1.14	3.80	1.03
	35	2.51	.99	2.84	.96	2.38	.96	2.66	1.00	2.44	1.06	2.60	1.01	2.11	.70	2.30	.82
Factor IV: Teacher Role	16	3.15	1.08	3.08	1.21	3.44	1.09	2.96	1.15	3.10	.95	3.06	1.10	3.59	.97	3.00	.82
	19	2.96	.73	2.85	.99	2.87	.83	2.98	.79	3.00	.43	2.97	.75	2.81	.74	3.30	.48
Factor V: Familiarity	2	3.54	1.13	3.85	1.24	3.80	1.08	3.49	1.11	3.47	1.15	3.55	1.14	3.56	1.09	2.89	1.05
	3	2.97	1.46	3.60	1.36	3.21	1.53	2.36	1.32	3.19	1.56	2.90	1.48	3.16	1.46	2.90	1.29
Impact	37a	3.40	.82	3.03	.86	3.73	.80	3.39	.78	3.43	.80	3.33	.81	3.83	.56	3.11	.78
	b	3.19	.87	3.03	.75	3.44	.81	3.05	.92	3.14	.94	3.07	.83	3.83	.64	2.78	.67
	c	2.73	.95	2.38	1.09	3.13	.99	2.69	.74	2.93	.94	2.66	.94	3.13	.63	2.33	1.12
	d	3.10	.91	3.00	.92	3.54	.88	3.05	.97	3.00	.85	3.29	.93	3.29	.81	2.88	.64
	e	2.82	.81	2.76	.74	2.57	1.09	2.69	.79	3.10	.76	2.96	.81	2.96	.75	2.89	.60

Table 8.11

Faculty Attitudes toward the TICCIT Program:
Responses by Department
Alexandria and Phoenix
Spring 1976

	Item Number	All Respondents (N = 184)		Math (N ≅ 21)		English (N ≅ 31)		TICCIT (N ≅ 29)		Alexandria (N ≅ 13)		Phoenix (N ≅ 16)	
		Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd	Mean	sd
Factor I: Global Judgments	5	3.52	.94	3.55	.69	3.25	1.00	3.55	.78	3.54	.66	3.56	.89
	24	3.63	.91	4.05	.80	3.42	1.16	3.66	1.17	3.69	1.03	3.63	1.31
	23	3.38	.95	3.10	1.00	3.10	.98	3.00	1.02	3.23	.93	2.80	1.08
	21	3.25	1.13	2.76	1.04	3.00	1.14	2.93	1.12	3.08	1.16	2.81	1.11
	26	2.95	.81	2.48	.87	2.66	.99	2.62	.94	2.62	.87	2.63	1.02
	6	3.50	.96	3.14	1.06	3.33	1.01	3.24	1.06	3.08	.95	3.38	1.15
	27	3.19	.86	2.71	.90	3.13	.92	3.00	.93	3.31	.75	2.75	1.00
	9	3.96	.85	4.10	1.14	3.56	1.00	3.79	1.21	3.77	1.01	3.81	1.38
	25	2.84	.92	3.38	1.02	3.07	1.09	3.14	1.13	2.85	.99	3.38	1.20
	10	2.91	.83	2.57	.68	2.75	.90	2.55	.87	2.54	.88	2.56	.89
	32	2.82	.76	2.19	.75	2.77	.83	2.41	.87	2.62	.77	2.25	.93
	36	2.96	1.03	2.38	.86	2.77	1.02	2.75	.97	2.83	.58	2.69	1.20
	7	2.90	.94	2.86	.96	2.87	1.06	3.04	1.10	3.33	.98	2.81	1.17
	33	3.09	1.10	3.81	.87	3.41	1.11	3.52	1.02	3.31	.85	3.69	1.14
	34	3.38	1.06	2.76	1.09	3.35	1.12	3.17	1.20	3.77	.83	2.69	1.25
	20	2.83	.99	2.60	1.10	2.52	.95	2.45	.95	2.69	.95	2.25	.93
	29	2.93	.89	2.48	1.03	2.77	1.02	2.59	1.15	2.85	.99	2.38	1.26
	30	2.59	.93	2.89	1.20	3.10	.99	3.14	1.11	3.33	1.07	3.00	1.15
Factor II: Management of Instruction	8	3.01	1.00	3.81	1.17	3.00	1.06	3.55	1.21	3.38	1.33	3.69	1.14
	31	3.93	.89	4.19	.98	4.23	.87	4.24	.99	4.31	1.11	4.19	.91
	22	3.22	.93	3.71	1.15	3.10	1.03	3.45	1.21	2.77	1.09	4.00	1.03
	18	2.98	.89	3.57	1.03	3.22	1.05	3.55	1.15	3.31	1.11	3.75	1.18
	15	2.83	1.05	1.76	.70	2.53	1.06	2.00	1.07	2.31	1.11	1.75	1.00
	4	2.89	1.11	3.72	.89	3.00	1.12	3.43	1.23	3.54	.97	3.33	1.45
	17	3.33	.83	3.71	1.06	3.42	.91	3.69	1.14	3.54	1.20	3.81	1.11
Factor III Program Limitations	13	2.06	1.02	2.67	1.32	2.00	.90	2.24	1.18	2.00	1.22	2.44	1.15
	28	2.82	1.07	2.95	1.20	3.29	1.25	3.14	1.19	3.31	1.38	3.00	1.03
	14	3.45	1.28	3.95	.94	3.41	1.25	3.71	1.08	3.38	.96	4.00	1.13
	35	2.51	.99	2.86	1.15	2.74	1.02	2.59	1.02	2.00	.71	3.06	1.00
Factor IV: Teacher Role	16	3.15	1.08	3.05	1.40	2.97	1.15	2.97	1.35	3.08	1.32	2.88	1.41
	19	2.96	.73	2.86	1.20	2.93	.73	2.83	1.14	2.77	1.30	2.88	1.02
Factor V: Familiarity	2	3.54	1.13	4.00	1.22	3.53	1.15	3.93	1.09	4.15	1.07	3.73	1.10
	3	2.97	1.46	3.75	1.25	2.26	1.37	3.29	1.44	2.92	1.61	3.60	1.24

Table 8.12

be well familiar with the TICCIT program by virtue of nearly two years of experience with the system in math courses. This division did not perceive the TICCIT program as one of the most significant developments in education (item 36) nor did the division believe the project warranted the resources which had been devoted to it (item 33). Judgments of TICCIT's impact on course completion (item 37c) perhaps explain these reactions: Faculty from the natural sciences knew that the program had a negative effect on course completion rates in mathematics.

It has been noted that administrators tended to view computer-assisted instruction more favorably than did instructors (see Table 8.8). Administrators also seemed to hold more positive opinions of the TICCIT program than did instructors, as shown in Table 8.11. No longer is greater familiarity with computers a viable explanation for this difference since administrators and instructors appear to be comparable in this dimension of their attitudes. Either the TICCIT program succeeded in generating favorable reactions among administrators or administrators missed the direct exposure that shaped instructors' opinions. The contrasts across divisions and positions suggest that those faculty close to the TICCIT program had a less favorable reaction to it.

Change. What changes in faculty attitudes occurred as a result of their exposure to the TICCIT program? There was little change in their opinions about student-computer interactions or in their global judgments of computer-assisted instruction. Faculty had thought that CAI would make students active in their own learning (item 27 on Form 002, mean 3.57) and that it would tailor instruction to the individual student (item 23 on Form

02T, mean 3.40). The TICCIT program met their expectations in both respects (items 5 and 6 on Form 003 with means of 3.52 and 3.50, respectively). Similarly, faculty did not perceive the TICCIT program as a passing fad (item 35 on Form 003, mean 2.52) consistent with their earlier attitude toward CAI in general (item 29 on Form 02T, mean 2.46). And they were unsure of whether or not the TICCIT program constituted a significant development in education (item 36 on Form 003, mean 2.96) just as they had been unsure about CAI (item 30 on Form 02T, mean 2.96).

There was an obvious shift in faculty attitudes toward the impact of computer-assisted instruction on instructors' responsibility. Faculty had earlier tended to disagree with the statement "CAI is a potential threat to the jobs of faculty members" (item 24 on Form 02T, mean 2.52) but they clearly disagreed with the same statement as it pertained to the TICCIT program (item 13 on Form 003, mean 2.07). Perhaps this further reduction in the potential threat posed by computer-assisted instruction can be attributed to a better grasp of the computer's strengths and limitations. Faculty had reported feeling greater comfort in working with computers (item 19 on Form 02T, mean 2.86, and item 2 on Form 003, mean 3.54). And part of this improved understanding might be due to a more realistic concept of the computer's impact on teachers. Prior to the implementation of the TICCIT program at the colleges, faculty generally believed that computer-assisted instruction would relieve instructors of routine duties and enable them to make better use of their capabilities (items 25 and 30 on Form 02T, means 3.70 and 3.58, respectively). After several academic terms of experience with the TICCIT system, faculty became unsure of whether the TICCIT program had affected instructor duties in such a way (items 16 and 15 on Form 003, means 3.16 and 2.84, respectively).

It is difficult to capture the descriptive portrayal of faculty acceptance and teacher role in a succinct and clear summary. This difficulty is perhaps inherent to a presentation which gives so much of the context necessary for appreciating what the treatment condition entailed. The first section of this chapter was intended to serve that purpose. It illustrated that instructors responsible for classes on the TICCIT system devoted substantial amounts of their time to assisting individual students with their course work. Since most of this time was spent in responding to student questions about the subject matter and monitoring student attempts at mastery tests, faculty did not fulfill the role of manager-advisor which the developers of the TICCIT program had envisioned for them. With regard to faculty acceptance, the TICCIT program had generally met the expectations of college staff for computer-assisted instruction. Faculty did perceive the program as tailoring instruction to the individual student and engaging students actively in their own learning. However, those instructors closely associated with the TICCIT project often reacted to the program less favorably than their colleagues. And instructors became less certain that computer-assisted instruction, particularly the TICCIT program, would benefit them in fulfilling their instructional responsibilities.

Chapter 9

Comments from the Developers of TICCIT
(The MITRE Corporation and Hazeltine Corporation)

The addition of a developers' chapter to this final report on the 1975-1976 TICCIT demonstration offers a unique and highly desirable opportunity to view educational research data from more than one perspective. As the developers of TICCIT, we wish to express our appreciation for the opportunity to contribute our comments concerning the demonstration and its evaluation.

Although, as might be expected, the developers and evaluators have occasionally differed concerning the interpretation and weight of research findings, the inclusion of this chapter is typical of the high level of cooperation between ETS and the developers through-out the demonstration period. This cooperation played a substantial role in the development of a successful TICCIT concept; in fact, several specific improvements in the TICCIT system and its use were made on the basis of early communications with ETS evaluators concerning the system's effectiveness.

This chapter has been divided into two major sections. In the first are comments reflecting the developers' views of the data collected by ETS. Our conclusions regarding the demonstration are drawn not only from the ETS data but also from studies conducted by the TICCIT users themselves. The second section briefly describes the evolution of the TICCIT system since the demonstration.

Before discussing developers' views, however, it would be appropriate to note that this chapter has been itself the product of extensive cooperation between several institutions. Such cooperation was necessary because a majority of the TICCIT system developers are no longer employed at the original developer institutions -- MITRE Corporation and Brigham Young University. Many of these individuals are now involved with educational consulting companies, including WICAT and Courseware, Inc. The largest group of developers to leave MITRE and BYU went to Hazeltine Corporation, which now offers the TICCIT product line on a commercial basis. The MITRE Corporation has coordinated the development of this chapter, drawing upon contributions not only from various of the institutions mentioned above but also from the TICCIT demonstration sites.

9.1 Comments on the TICCIT Evaluation

As developers of the TICCIT system, we have been extremely gratified by the results of the community college demonstration. The design, development, implementation, and demonstration of the TICCIT system in four years required a mammoth undertaking. The use of TICCIT instruction was a radical departure from the traditional classroom instructional approach, and it might be said that a comparison of such a new method as untested as TICCIT against a method as well established and tested as classroom instruction would be a very difficult one. Indeed, the implementation of TICCIT instruction was certainly adversely affected by faculty and student skepticism as well as by the typical problems of a new system under development, including serious delays in production and debug schedules of hardware, software, and courseware. Yet, in spite of the obstacles, during the first year and a half of its operation, the TICCIT system had an unquestionably positive impact upon student achievement in both math and English. The TICCIT system worked: students learned and continue to learn the assigned objectives, faculty learned to use the system effectively in many instructional programs, and administrators have continued to approve the allocation of institutional resources for TICCIT programs.

As developers, however, we were disappointed by the low completion rates. In attempting to find causes and solutions for the problem, several innovative instructional management procedures have been implemented which have significantly improved TICCIT completion rates. In fact, in some cases, completion rates have surpassed those in comparable traditional classes.

The major purpose of this comment is to consider the ETS data as well as data collected by the user colleges themselves during and since the demonstration to gain a broader perspective of the educational impact of the TICCIT system. The first two sections discuss ETS and college data concerning student achievement and completion rates, respectively. The third section discusses the impact of the role of the instructor on completion rates and postulates that the predominant cause of the demonstration's low completion rates was the lack of a coordinated management scheme rather than an inherent TICCIT bias against students of lower entrance ability.

9.1.a Student Achievement

Math. A number of different types of analyses of the math achievement are contained in the ETS report. The first analysis involved eleven comparisons of TICCIT math sections and lecture sections of the same course taught during the same academic term. The posttest scores of students beginning and completing a TICCIT course within one term were compared to the posttest scores of lecture section students of the same entrance ability, where entrance ability was measured only by the pretest administered at the beginning of the term. In eight of the eleven cases, the TICCIT students scored higher on the posttest. Levels of statistical significance were seen in only two of the eleven cases; both cases of significantly higher scores favored the TICCIT students. Such results are encouraging but certainly not overwhelming.

However, it must be recalled that the TICCIT courses were "self-paced" and that no external schedules to complete within one term were imposed upon the TICCIT students. As in many other self-paced environments, completions within a single academic term were low in number among the TICCIT sections. To expand the number of student observations being considered, the second ETS analysis dropped the time limitations of a single academic term. There were six different math courses at the two community colleges that were so analyzed. In other words, the achievement of all students who finished a given TICCIT math course during the academic year was compared to the achievement of similar students finishing a lecture section of the same course. In that analysis there were significant achievement differences in five of the six courses. All five favored TICCIT.

A third analysis in the ETS report examined ability and content subscores for math posttests to discover particular strengths or weaknesses in TICCIT instruction. As might be expected, the number of items for each type of ability or category is small. ETS analysis indicated that although some of the subscores did approach reliability for group measures, most did not, making any outcomes more descriptive than conclusive. Few of the categories resulted in significant effects; only two significant effects were repeated across terms, and both were in favor of TICCIT. Solution of routine problems as an ability level involved positive TICCIT effects in every case and significant effects in two courses. The other repeated significant positive effect involved the content category of equations. These specific strengths must be attributed to the depth of coverage of each topic in a TICCIT course and the extent of practice opportunities. In general, in those areas of the math curriculum considered to require the highest ability and to be most advanced, TICCIT outcomes showed consistently positive effects.

Generally, the effects of topical tests follow the pattern found in posttests. Although only one of the results was significant at acceptable levels, in four of the cases the results show a sizeable point difference which represents a positive TICCIT effect equivalent to ten percent of the total possible score on the tests. Another indication of the positive impact of TICCIT upon achievement is the fact that these results apply to a wider range of students than those taking a posttest since the topical test were administered earlier in the term to a larger number of students.

English. Only cumulative learning as indicated through posttests was analyzed by ETS for achievement effects in English courses. The posttests themselves were divided into two parts. An objective test called for responses to multiple-choice questions about grammar and writing structure; the second part of the test required the students to write an essay on a given topic.

In those English courses in which TICCIT was used as it was intended to be used, as a mainline instructional source, there were consistent and statistically significant differences, favoring TICCIT over lecture sections, on the objective test of writing skills. Student performance on essay tests was also better in TICCIT sections, except in a situation in which a part-time instructor unfamiliar with TICCIT conducted the TICCIT class.

On the other hand, when TICCIT was not used as the primary source of instruction, achievement effects were mixed. In those classes using TICCIT adjunctively, only students of relatively high ability experienced gains on the posttests. Those TICCIT students of low entrance ability scored lower on posttests than similar students in lecture sections. Use of the system merely as a supplement to classroom instruction simply does not yield the same consistency of positive gains found with the mainline applications in both English and math.

At BYU, there were also two measures of achievement. All TICCIT and non-TICCIT students were given a departmental objective test of writing skills and a university-administered writing competence exam of objective and essay skills.

There were no significant differences in the scores on the departmental exam. However, the exam had not been carefully designed to take into account the differences in the TICCIT and non-TICCIT course outlines as had the ETS exams. The departmental exam had been designed for the non-TICCIT courses.

For essay tests and for overall pass/fail ratio on the university-administered English composition exam, TICCIT students did significantly better than non-TICCIT students. Over a three semester period, BYU tested 160 TICCIT students and 137 non-TICCIT students who had had the same instructor. Approximately 65% of the TICCIT students passed the exam compared to only 56% of the non-TICCIT students, primarily due to the fact that TICCIT students achieved higher scores on the essay component of the exam.

Summary. TICCIT exerts a significant and positive impact upon student achievement. For five out of the six observed math courses significant positive results occurred, often resulting in TICCIT posttest scores at least ten percent higher than lecture, corresponding to two-thirds of a standard deviation. In addition to overall higher achievement on posttests, TICCIT promoted higher achievement in the ability of students to solve routine problems and was equal to lecture in prompting adequate performance in the most advanced content areas of the math curriculum. In four of the six math courses, students in TICCIT courses scored about ten percent higher on topical tests of immediate learning than similar lecture students. In English, results for courses comparing TICCIT as designed and lecture likewise demonstrated significant positive effects for TICCIT students, resulting in an estimated difference of five percent in scores on objective tests of writing skills. Except where inexperienced instructors affected results, TICCIT students also scored higher in essay tests.

9.1.b Course Completion Rates

The percentage of students completing TICCIT courses within an academic term varied trenemdously among the various applications of the system. The most reasonable explanation for the variations appears to be the environment in which the TICCIT student learns. In existing literature, it is fairly clear that without some type of external management effort, fewer students will complete an individually-paced course than an instructor-paced course (Atkins & Lockhart, 1976; Coldeway & Keys, 1976; Coldeway, 1974; Lloyd, McMullin, & Fox, 1974; Coldeway & Scheller, 1974).

In the traditional classroom situation, motivation to complete the course within a given time frame is to some degree built-in, usually in the form of scheduled assignments and tests. To supply the motivation to complete the course on schedule in an otherwise self-paced TICCIT environment, the instructor must adopt the role of manager/advisor, providing individual students with progress and achievement goals and evaluating each student's performance in relation to those goals. Completion rates in TICCIT courses will depend upon the extent to which an instructor adopts that role.

In the original community college implementation, there was no emphasis upon completion as a program outcome; however, early in the demonstration it became apparent that high completion rates would not be achieved without a more structured environment. Therefore, the TICCIT users at BYU established the use of TICCIT in environments which included a weekly scheduled class meeting, small group discussions, individual student/teacher meetings, scheduled quizzes, or other features designed to motivate the student to complete within the academic term.

The BYU model produced TICCIT completion rates generally higher than in comparable lecture sections. In math, the average completion rate for classroom instruction was 65%. Classes taught by one of the TICCIT math authors averaged higher rates than classroom rates. Two classes taught by teachers previously unfamiliar with TICCIT were mixed; one had a completion rate of 72%, the other 33%. Rates for TICCIT English classes were very favorable, ranging from 88% to 96%. Those rates exceeded the very liberally-calculated completion rate of 82% for the classroom (the lecture sections did not include in the rate calculation any of a large number of students withdrawing before the third week of class, although the TICCIT sections did). Clearly, when efforts are expended to obtain high completion rates, it is possible to do so in an environment which attempts to pace students within certain time periods.

Although the community college implementations of TICCIT did not generally include such concerted efforts to increase completion rates, the TICCIT English instructors were generally very imaginative in their approaches to directing the TICCIT classes, using features such as class meetings and group discussions. It was apparent that those efforts did result in completion rates that, although lower than lecture classes at the community college, were significantly higher than those in math classes in which there was basically no effort to pace student learning according to any schedule. In three of the five cases in English there were significant negative impacts upon completion attributable to the TICCIT condition, but in every case the English completion rates were substantially higher than found in the TICCIT math sections. The rates for English were generally 10% to 20% lower than classroom completion rates, which ranged from 60% to 75%.

The math courses at both community colleges were generally implemented without any of the tools discussed above that would tend to motivate pacing within the academic term. Total self-pacing was the rule for math classes; there was no penalty for re-enrolling for the same course in subsequent terms. There appeared to be little or no discussion with individual students concerning learning pace, and there were no group or class discussions. The results of the analysis do show significant treatment effects upon completion. In 10 of the 12 math classes analyzed, significant (at $p < .001$ levels in all but one case) and negative treatment effects were associated with the TICCIT sections; the two remaining sections showed no significant treatment effects. The rates for TICCIT sections were generally about half the size of lecture rates, which were about 40% to 55%.

Implementations of more stringent management efforts at the community colleges since the demonstration have resulted in substantial increases in the TICCIT completion rates. The latest figure from one community college shows a completion rate in TICCIT English (72%) which surpassed the rate in the lecture sections. The other college has reported completion rates in math which indicate that when allowing students three quarters to complete a course, slightly more TICCIT students (48%) than lecture students (44%) complete the course.

9.1.c Comments on Completion Rate Data

Those who continue to develop and market the TICCIT system have been very pleased with TICCIT evaluation results. The achievement data consistently demonstrate significant and substantial positive gains for TICCIT students in both math and English. The measure of success for TICCIT was to be its impact upon achievement compared to traditional instructional methods. In that light, it must be said that even in its initial operation, TICCIT was highly successful, teaching math and English students often better than was done in traditional classes.

Perhaps the most gratifying results were found in the English composition courses. Efforts to develop computer-assisted materials for composition instruction were met with constant skepticism. Yet, the evaluations have shown that completion rates in TICCTT English classes have been similar to or surpassed completion rates in lecture classes. More important was the finding that those students completing TICCIT scored consistently higher on objective and essay posttests.

Similarly, students in TICCIT math classes performed consistently better on course posttests and on topical tests than their counterparts in lecture sections. Although completion rates for the highly managed environment did surpass lecture rates, the rates for TICCIT math classes within the evaluation context were disappointingly low. Completion was not an outcome highly emphasized during the demonstration, but the higher completion rates found in the BYU study would have been just as desirable in the community college setting.

A very important question for those involved in current development of TICCIT and CAI in general is why completion rates in math were so much lower at the community colleges than the English rates, especially since the two courses were basically identical in design. It has already been suggested that the difference lies chiefly in the degree of instructor involvement in managing student progress.

The explanation for generally lower TICCIT completion rates apparently favored by ETS was that the TICCIT system itself may favor students of high ability to the detriment of low ability students. While the completion rate figures for the math courses do appear related to entrance ability, the figures relate to completion within a single term. Such results relate more to the speed of acquiring mastery of the objectives rather than to the ability to master the objective at all. This consideration and others which are discussed below tend to dispel the notion that TICCIT is suitable only to "high ability" students.

The ETS conclusion concerning ability is based upon the observation of differences in pretest means of students finishing the course in TICCIT sections and those students finishing the lecture sections. The differences in the fall terms were particularly large. However, in later terms the differences in pretest mean scores became much smaller, primarily because of the addition in later terms of the scores of students taking more than one term to complete. The effect of this can be seen in the analysis of the fall term of beginning algebra at Phoenix. The pretest mean for students finishing TICCIT was 44.86 while for lecture it was 41.28. Logically, one might conclude that any difference in posttest scores (actual scores for TICCIT and lecture were 40.06 and 38.82, respectively) must be due to the high entrance ability. However, further analysis limiting the comparison to higher ability students (defined in this case by pretest scores greater than or equal to 35) still showed positive achievement effects. Later analysis eliminating the constraint of completions within a term included a sizeable group of students who had completed TICCIT math during the spring semester. The mean pretest score of this group was 33.92, which is below the earlier defined high ability level of 35, below the pretest mean of lecture students completing the fall semester (38.64), below even the mean of the lecture students from the fall who did not finish within one term but also completed in the spring (34.62), and below the mean pretest scores of all students taking the pretest. Yet this broadening of the applicable entrance ability did not subtract from the overall achievement results. In fact, as mentioned earlier, the inclusion of all the students requiring more than one term to complete increased the impact of achievement results. Although the view of the TICCIT completion and achievement results within a single academic term appears to support an argument for TICCIT suitability only to high ability students, the results across terms weakens the argument with the inclusion of substantial numbers of students with much lower entrance abilities who, nonetheless, add a greater degree of significance to the positive achievement data. It does appear that students with higher pre-test scores are able to finish TICCIT courses faster than those with lower scores, a finding not unusual with individually-paced learning systems.

An additional factor which weakens the high entrance capability argument is the topical test analysis. For topical testing, an even broader segment of the student population was included. Unfortunately, no detailed analysis is made of students completing topical tests in terms of entrance ability. The comments in the evaluation imply that the group taking the topical test more inclusive than the group completing TICCIT but did not include the entire population beginning the course. The students were characterized as those able to make progress towards completion on TICCIT. Again with the enlarged population, there are still substantial achievement gains for TICCIT students in five of the six courses. Although the data are not clear, the implication from the topical test results is that the entrance ability argument must be still further weakened.

The ETS report seems to imply that the topical test results reinforce the argument that TICCIT is suitable for students of higher ability because the TICCIT population taking topical tests was still smaller and more select than the population originally enrolled in the course. That fact might be interpreted as evidence in support of the contention that TICCIT is better suited to highly capable learners. But the context of that evaluation is a comparison of TICCIT and traditional instruction; therefore, the statement that TICCIT would be suitable only for high ability students implies that the lecture condition has a less negative impact than TICCIT upon those of lower ability. It is clear from ETS data, however, that the traditional instructional method also exerts a strong bias against the lower ability student. The issue then is not simply whether TICCIT exerts a bias against low ability students but whether that bias is significantly greater than that already existent in traditional instruction. Without substantial differences between any bias exerted by TICCIT and bias exerted by lecture methods, the statement that TICCIT is suitable for high ability students could not be justified. On the basis of the results of across-term analysis and topical testing discussed above, there do not appear to be such differences to justify the conclusion that TICCIT applications should be limited to those involving only highly capable learners.

Further arguments against the general hypothesis that TICCIT is not suitable for students of less than high ability are found in the following observations. First of all, the math courses under consideration were fundamental courses in community colleges with very liberal enrollment policies. A large number of the classes for which data were taken did not qualify as college credit courses but were developmental classes to compensate for pre-college deficiencies. They are necessary and important courses, but it may be difficult to support any general statement concerning "high ability" students on the basis of observations only from these courses. Perhaps even more interesting is the relationship between two of the courses at Phoenix. Generally, students enroll in Math 007 only because they have not demonstrated the entrance ability, as judged by performance on a pretest, required for Math 106. By definition, all students in Math 007 would be of lower entrance ability (i.e., lower pretest scores) than those in 106. Yet the analysis for Math 007 demonstrated one of the strongest positive effects for TICCIT students.

In short, there appears to be satisfying evidence that TICCIT can be successfully applied in learning environments in which there are varied entry abilities. Although entrance ability must be considered when implementing TICCIT, the consideration should not preclude those of low entry levels. TICCIT was built on a mastery hypothesis; that is, given adequate instruction, defined as having a complete learning hierarchy, properly stated rules with alternate versions of the rule, and extensive files of examples and practice problems with helps, any student with the prerequisites for a given lesson could, given enough time, pass that lesson. The TICCIT math course assumed a minimum set of prerequisites for entering students. The effect of not having the prerequisites was more pronounced in math than in English since math is a cumulative subject. Large numbers of the community college students did not possess the minimum prerequisites required by TICCIT, yet they were allowed into the TICCIT courses as they were allowed into the lecture courses. The design philosophy of TICCIT does not specify that all students who lack the prerequisites would be able to succeed -- no matter how much practice on a higher order math skill they were able to engage in. Rather, the TICCIT design hypothesis is that for such students, other TICCIT lessons could be developed which would give them the prerequisites needed to enable them to complete the higher lessons in a manner most efficient for their particular learning rate and aptitudes.

Evidence that the students did lack the necessary prerequisites is found in the large numbers of students who were not able to complete the first TICCIT unit or who took an extremely long period of time to do so. Once students were able to complete the first unit in math, chances for their successful completion of the course were greatly improved. However, it cannot be said that the TICCIT system itself is inadequate if students not possessing the presumed prerequisites have difficulty achieving mastery on higher order lessons. If the ETS data are viewed as formative evaluation data, it is clear that the hierarchy must be extended downward and that existing material should be simplified. That the model is less effective for less able students does not seem to be a valid conclusion.

The entrance ability hypothesis does not explain adequately the low completion rates in the community college math courses. Comparing the completion rates of math to those of the self-paced programmed instruction makes it reasonable to assume that the problem of low completion rates is a generic problem with self-managed instruction. The rates found in TICCIT were comparable to the rates in the self-paced programmed instruction at Alexandria and to the historical rates of similar programs at Phoenix. The evaluation report mentions the problem a number of times, referring, for example, to the fact that many students failed to attend classes regularly, or at all, when pressures from other non-self-paced courses increased. Records of the number of hours spent on-line also indicated that students not completing the course spent fewer hours on the system than the number of hours assigned for classroom usage in the lecture sections. (For example, a study conducted by Alexandria indicated that average usage for students not completing TICCIT sections was approximately 30 hours. The lecture sections met for 50 hours per term.) There is apparently a problem with the management of student progress which greatly contributes to lower completion rates.

The management problem is not surprising, however. From the beginning of the project, TICCIT developers understood that such problems existed with self-paced instruction and did attempt to create solutions in advance. The TICCIT math and English courses were both designed to be implemented in an environment in which the instructor took an active role in the management of student progress (Black, 1974; Bunderson, 1973). The originally defined role of manager-advisor to be assumed by instructors included goal-setting and performance evaluation behaviors. Such a model was implemented much more fully in the English than in the math courses. As has been seen, completion rates in English were higher; in fact, the lowest completion rate in any English course was higher than that for any math section.

The English and math course designs themselves were simply not divergent enough to result in such large completion differences. However, a review of the implementation contexts shows striking differences. ETS observed that English instructors took an active role in prescribing study materials, conducting small group discussions about common difficulties, and handling individual student problems. On the other hand, math students had much less instructor contact, and the great majority of contact that did occur was centered on content problems rather than individual progress problems. At Phoenix, students were not even assigned to particular math instructors; consequently, the instructors assigned to the lab in a given hour may not have been able even to identify individual students. In short, there appear to have been substantial differences between both the quantity and quality of instructor interaction with math and English students.

It is perhaps understandable that better management efforts were not implemented. The developers did attempt to provide features in the system, such as various reports concerning individual student progress, but for various reasons no systematic method of handling the management problem was provided. It is to the credit of the colleges themselves that programs were developed in the English courses that did improve student completion rates through better management. The methods implemented, including small group discussions and closer involvement in individual assignments, could and should also be used in mathematics. The possible impact of management was not discussed in the ETS evaluation of math completion rates, possibly because none of the math sections dealt with the problem and because no obvious solutions to the problem were ever suggested or implemented. But because of the basic similarities between the courses, there is reason to believe that similar management efforts would also increase math completion rates. The evaluation did indicate a strong correlation between time spent on-line and the number of math lessons completed. To improve the rate of completion, it would appear then that measures are needed to improve student motivation to spend an adequate amount of time on the system.

Further evidence for the efficacy of management efforts is found in the BYU math implementation, discussed earlier in the completion rates section, in which TICCIT completion rates did exceed those of the classroom. The literature would also support the hypothesis that increased management efforts will result in higher completion rates (Lloyd, et. al., 1974; Miller, Waver Semb, 1974; Malott & Svinicki, 1969).

The developers were highly pleased with the results of the evaluation. Very clearly positive achievement results for instruction in English was a result expected by very few people. Yet the results do show that grammar and composition can be taught systematically with positive effects on student writing capabilities. Even in the initial year of implementation of a radically new instructional method, nearly as many students finished the course with TICCIT as with the established instructional method and performed significantly better on achievement tests. As instructors have become experienced with the system, its effectiveness continues to be manifested: completion rates now often exceed those of the classroom. Achievement for math students on TICCIT is equally pleasing. Distracting slightly from that enthusiasm were the lower completion rates found with the math sections within the ETS evaluation. However, the developers find no reason to believe that there is any inherent characteristic of TICCIT instruction that would prohibit completion in math from being equal to that found with English. There is ample evidence, including already improved completion rates, that the management techniques used to improve completion for English classes are just as effective in promoting completion rates in math comparable to or exceeding those in lecture classes. TICCIT is a very powerful instructional tool, one which should continue to have a great impact on the future of educational practices.

9.2 Post Demonstration Developments

Over the past few years, the TICCIT system has continued to expand and develop. Several significant events in the system's recent history include the commercialization of the system and the installation of four new TICCIT systems, two for military training and two for special education. Application of TICCIT technology to new training situations and subject areas has also continued at the demonstration community colleges and Brigham Young University. Since Hazeltine Corporation acquired commercial rights to the TICCIT system, the TICCIT concept has continued to evolve in many directions. In conjunction with its uses in many different instructional and training situations, the TICCIT system will continue to implement state-of-the-art technology to solve the needs of its users in the most effective and efficient manner possible.

9.2.a Commercialization of the TICCIT System

One of the major goals of the developers of the TICCIT system was the creation of a commercially successful computer-based instructional system. The first step toward achieving a market success was to secure a commercial firm to manufacture and market the TICCIT system following the initial demonstration. Thirty companies formally evaluated the TICCIT system as a potential product line, eight of which carried on extended dialogues with MITRE and NSF. Of the eight, MITRE selected Hazeltine Corporation, partly because of Hazeltine's commitment to continue the development of the system and the support of the existing TICCIT installations.

In late 1976, Hazeltine Corporation acquired the rights to the TICCIT system and began commercial marketing of the system.

9.2.b New TICCIT Installations

Even before Hazeltine Corporation acquired commercial rights to the TICCIT system, several institutions were interested in purchasing TICCIT systems. Before the end of the TICCIT demonstration at the community colleges, the MITRE Corporation custom-designed and installed TICCIT systems at North Island Naval Air Station in San Diego, California; Cecil Field Naval Air

Station in Jacksonville, Florida; at the Model Secondary School for the Deaf (MSSD) on the campus of Gallaudet College in Washington, D.C.; and in Amherst, New York. With these four systems, TICCIT technology was applied to two new fields of instruction -- military training and special education.

Military Training. The TICCIT system is currently being used for air crew training for the S-3A Viking antisubmarine aircraft. Initial results from a program evaluation at North Island Naval Air Station indicate that the TICCIT system is a significantly more efficient training medium than the traditional media. Through the use of TICCIT instruction, training time was reduced by as much as one half (Walker, 1978). The Navy is continuing its use of the TICCIT system for S-3A training and development of TICCIT courseware.

Special Education. The TICCIT system is currently being used in two very innovative special education projects.

In Amherst, New York a custom-designed TICCIT system is used to deliver computer-based instruction, games, and simulations to the homes of homebound handicapped children. The children receive interactive instructional displays directly on their home television sets and interact with the displays using a special keyboard and telephone link to the system's central computer. The project, serving 100 families, is the first to attempt such large-scale home delivery of computer-based instruction.

At the Model Secondary School for the Deaf, located on the campus of Gallaudet College in Washington, D.C., the TICCIT system is being used to deliver instruction to and facilitate communication between deaf students. The MSSD's TICCIT system is integrated with the school's closed-circuit cable television to provide a wide range of services. The MSSD student terminals are used interchangeably for computer generated instructional displays, commercial and local television broadcasts, and terminal-to-terminal video communications.

9.2.c TICCIT Demonstration Sites -- An Update

Some of the most convincing evidence of the TICCIT system's success may be gleaned from a look at the current status of the system at both of the demonstration community colleges and Brigham Young University. All are actively used for courseware development, the delivery of instruction, and research. Since the demonstration, all three institutions have expanded their systems as well as their applications of TICCIT instructional technology.

Brigham Young University. Since the end of the demonstration period, BYU's TICCIT system has undergone several dramatic changes. With the end of the demonstration, BYU's role as the primary courseware development system for the community colleges ceased. The TICCIT system had to find a role within the university. After serveral moves, the system is now located in the Learning Center in BYU's new Harold B. Lee Library and has been integrated into the Department of Learning Services where it is used for research, courseware development and instruction in English, Math, French, Italian, Reading, Nursing and English as a Second Language. BYU also has plans to expand their hardware system to permit the storage of even more courseware through the addition of two twenty-five megabyte disk drives.

Northern Virginia Community College. Since the demonstration period, the TICCIT system has been fully integrated into the campus Learning Resource Center where it continues to be used to teach both English and Math. Toward the end of the demonstration period, NVCC launched a courseware development effort to revise portions of the demonstration courseware and to create new course materials. NVCC is experimenting with several new applications of the TICCIT system, including a biology testing program, an adjunctive English grammar course, and chemistry and poetry course modules. NVCC will also be developing a new math course for science students under the National Science Foundation CAUSE and Local Assessment grants. NVCC will also make major hardware improvements to their system, with the addition of memory, a new disk drive and character generator.

Phoenix College. The TICCIT system at Phoenix College has been fully integrated into the freshman English program, delivering both remedial and freshman composition courses. In addition to its role in the English program, the TICCIT system is being used to deliver instruction in remedial math, fire science, and medical terminology.

Phoenix College is currently exploring the possibilities of expanding its TICCIT system through the addition of a new disk drive. In addition, Maricopa County Community College District is considering expanding the use of TICCIT instruction to several other of their college campuses.

9.2.d Current System Developments

Improvements in and enhancements to the TICCIT system have occurred continuously since the beginning of the demonstration period in 1974. Some of the modifications were designed to correct specific problems encountered during the demonstration period, while others constitute new features that should broaden TICCIT's capabilities.

As a result of the demonstration period, the TICCIT test model was expanded, the advisor program revised and inter-communication features added. Because the original "tailored testing" model proved too restrictive to courseware authors, a second testing method was developed in order to allow the administration of tests with a fixed number of items and passing percentages. Although the "tailored testing" model is still used for most tests, the new fixed-length model expands authoring alternatives and greatly simplifies many applications of TICCIT. In addition, the Advisor program has been modified to improve the quality of advice given by the system. Finally, because of the need to get in touch with students working outside of classroom hours and the need to locate and communicate with students at work, a number of communications features were added to allow each user to pass messages via "mailboxes" and to allow inter-terminal communications. Using "mailbox", an instructor can leave messages, information, content or schedule comments for students, and students can leave "mail" for other students as well as for the instructor. The inter-terminal communications system makes it possible to any user to communicate in real-time with any other user on the system.

Continued development of the TICCIT system by Hazeltine has resulted also in several major advances. Improvements have been made in all major TICCIT subsystems, including hardware, software, and courseware.

Hardware improvements in the computer and display generation subsystems have resulted in lower purchase and maintenance costs and increased system reliability. Because of recent technological advances, the TICCIT system now consists of fewer hardware components yet performs more efficiently than previous versions of the system. The computer subsystem now uses the most advanced minicomputer and mass memory devices, making it possible to support a complete TICCIT system using only one minicomputer rather than the two required previously. In addition, the moving head disk storage capacity has increased substantially, allowing a 75% decrease in the number of disks needed per system.

The display generation subsystem has been updated with state-of-the-art solid state memory devices. As a result, the new display refresh memory uses approximately 70% fewer printed circuit boards than previous TICCIT systems. This reduction in the number of components and interconnections has been a major factor in reducing purchase and maintenance costs and increasing system reliability. Additional improvements in the circuit design of the TICCIT student terminal have produced an even better TICCIT display quality than was previously possible.

The TICCIT software system has also been improved. The operating systems originally developed for the TICCIT system have been revised, greatly increasing the flexibility and reliability of the system. This new software facilitates a single-computer system configuration, flexibility in the use of disk space, and the addition of special-purpose devices to the system.

A new courseware authoring facility called TAL (TICCIT Authoring Language) has greatly improved the flexibility afforded TICCIT authors. TAL complements the original highly structured authoring procedure and provides a general purpose authoring capability that takes full advantage of existing TICCIT display construction and response analysis features. TAL has been specifically designed to expedite the authoring of many different types of instruction, including simulations, interactions with training devices, games, and drills.

A recent addition to the TICCIT program is a self-contained, four terminal, transportable system. Hazeltine is using this system to demonstrate major TICCIT capabilities at national conventions and trade shows. Marketing representatives are also showing the unit at potential users' facilities, demonstrating with the users' own materials how a TICCIT system might be used in their training program.

9.2.e The Future of TICCIT

The use of minicomputer and television technology and the advances in video disk and microcomputer technology will play important roles in the future of the TICCIT system. Video disk technology will greatly improve the system's ability to present pictorial information and rapidly access instructional TV segments as part of complete courses of instruction. The video disk in conjunction with microcomputer technology opens the way for TICCIT applications in locations where one or only a few terminals are needed. For these terminals, there will be no requirement for telephone line connections to a remote computer.

The economic benefits of the TICCIT system will also continue to increase. The reduction in cost and improvement in capabilities of the components that make up the TICCIT system will lead to successive improvements in the system's overall cost effectiveness.

Since its original demonstration, the TICCIT system has been an extremely valuable resource for improving instruction. Building upon that record, the system will continue to provide the foundation for successful training and educational programs.

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